

TRANSACTIONS

American Society for Steel Treating

VOL. X

SEPTEMBER, 1926

NO 3.

CHICAGO AND THE A. S. S. T. CONVENTION AND EXPOSITION

THOSE of us who have grown up with the results and have had the comforts of modern manufacture around us are apt to miss the romance surrounding its development.

Especially is this true of the development of iron and steel products which enter so largely and so intimately into our every-



Recreation Pavilion, Municipal Pier

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day life that we do not realize what a tremendous asset they are to society. And it is only when we stand off and view the marvelous development in the steel world—get a perspective of it—that we really sense the gigantic strides that have been made which add so materially to the welfare and well-being of the human race.

The place to get a perspective of progress and development is

at an exposition. That is the primary purpose and aim of conventions and expositions—to show what has and what can be accomplished. Such is the purpose of the convention and exposition of the American Society for Steel Treating which will be held in Chicago, September 20-24, 1926.

This will be perhaps the greatest exhibition of machinery and heat treating equipment ever held in the world. Proof of this



Michigan Boulevard Looking North

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sweeping statement will be unnecessary when everyone realizes that there will be on exhibition on the 85,000 square feet of floor space on Municipal Pier the latest and most improved types of machinery, many of which will be in operation and shown for the first time.

During the technical sessions which are to be held in the Ball Room of the Drake Hotel, new machinery, new methods of making and heat treating iron and steel, results of innumerable investigations, the findings of scientific men engaged in research work, and new combinations of elements for specific purposes, will be set forth in manuscripts and discussed by men from many lands, notably, England, France, Germany, Japan and America. Many new ideas will be brought forth and a greater and finer spirit of co-operation between men engaged in the iron and steel industries will result in better products, larger profits and greater comforts

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for the entire human family. Applied ideas result in progress.

Chicago seems to be the great convention and exposition city of America. The great exposition of 1893 was held in Chicago as a result of the sheer ingenuity, hard work, persistence and skill of Chicago business men who won for Chicago the vote of Congress



The New Union Railroad Station

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to have the World's Columbian Exposition which commemorated the four hundredth anniversary of the discovery of America. The spirit of youth is "to dare to do" and Chicago is a youthful city, even now. In this exposition all the world was bidden to participate. Interesting exhibits of the arts, industries, manufacturies, products of the soil, mines, sea and air from all quarters of the globe were displayed. If art had a noble triumph, so likewise had industry and invention, for never before was so much material gathered together to show the progress of the nations or to teach the brotherhood of the human race. It was a delight, an education, a marvel,—and its influence was felt everywhere it touched human individuals.

The site chosen for this stupendous World's Fair, for such indeed it was, was Jackson Park located in the southeastern part of Chicago on the shore of the lake. The park covers an area of about 700 acres, 108 acres of which are ponds and lakes. The cost of the exposition exceeded \$20,000,000. One hundred and fifty

buildings were constructed of a treated composition which gave the effect of marble and hence it came to be called the "White City."

Chicago has, ever since that eventful occasion built for a better, healthier and happier city. The marvelous symmetry, unity, balance, and order which made the World's Fair a great artistic and financial success, began, in 1894, to be applied to the grouping of Chicago public buildings. In this, the city has been materially



Some of the Buildings of the University of Chicago *Kaufmann & Fabry*

aided by the efforts of the Commercial Club of Chicago which twelve years ago created a scientific and comprehensive plan for the future development of a city which every civilized nation on the earth considers a marvel of the century. The business men and public officials have given of their time, money and energy to carry out this plan. Fifty-four great public improvements are under way designed to enable Greater Chicago to expand industrially and commercially in an orderly and systematic manner. These plans contemplate extensive improvements along the lake shore and no city in the world has provided more lavishly than has Chicago for outdoor recreation. Chicago's greatest natural possession is its water front. Municipal Pier is a part of the shore line project just north of the Chicago River, the vortex of the city's shipping industry, and extends three-quarters of a mile into the lake. Steel steamers leave at frequent intervals from this pier for a cruise along the lake front.

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Chicago abounds in resources for the entertainment of its visitors and the city is becoming a veritable mecca for tourists. Chicago is said to have the most extensive park system in the world. It has 14 large and some 197 small parks. Its 143 municipal playgrounds furnish entertainment for thousands of children as well as adults and are considered the best in the world. Other



The Field Museum

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cities, at home and abroad, are giving considerable time to the study of the methods and plans adopted by Chicago. About 5000 acres of land are given over to parks and 100 miles of drives and boulevards have aided materially in making Greater Chicago an organic whole.

Chicago's downtown playground is Grant Park situated in the southern part of the city and contains about 210 acres of ground which has been mostly reclaimed from the lake. It is to the east of the business section of the city between the lake and Michigan Boulevard. Here are located the Art Institute, the equestrian statue of Logan by Saint-Gaudens, Taft's famous Fountain of the Great Lakes and the great stadium which adjoins the Field Museum of Natural History. The new Field Museum which fronts on Grant Park at Roosevelt Road covers 11 acres of land and cost approximately \$8,000,000. The exterior is of white Georgia marble, 80 feet high and is of Ionic Greek architecture. Its four departments of anthropology, botany, zoology, and geology contain rare and interesting exhibits. Here may be seen the largest collection of meteorites in the world; ores from the principal mining districts

of the world and models of machinery to illustrate the process by which the metals are extracted. In the zoology department may be seen wonderful displays of animal life, African game animals



Entrance to the Art Institute

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American birds beautifully grouped, and the hall of fishes which is unusually interesting.

The Art Institute is situated at Michigan Boulevard and Adams Street and contains splendid collections of old and new painters, ancient and modern sculpture, Egyptian, Greek and Oriental art. And here the student of art will find one of the most complete courses of art offered in America.

Lincoln Park is on Lake Shore Drive at North Avenue. It has a fine lagoon about a mile in length for launches and pleasure craft and is spanned by a unique high bridge. The aquarium contains native and the game fish found in American waters, and strange fish from Hawaii and China in wonderful colorings. The fish hatchery is located in the basement of this building. The conservatory contains many rare and beautiful plants and the zoo has over 2500 specimens of mammals, reptiles and birds which is said to be the finest collection in captivity.

The Midway Plaisance, a fine boulevard over 600 feet wide and a mile long, connects Jackson and Washington Parks and at its

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The Wrigley Building

Photograph by Kaufmann & Fabry

western limit may be seen Taft's beautiful allegorical "Fountain of Time." Washington Park contains some 375 acres, 23 of which are lagoons. Its charming driveways and conservatory make it an interesting place to visit. Humboldt Park is the largest and most beautiful of the west side parks and contains a water court, music court, fish hatchery, tennis courts, baseball diamonds and other attractive features for those seeking outdoor recreation. Just outside of Chicago more than 22,000 acres of forest preserves allure the tourist. Well-beaten Indian trails and other evidences of Indian days still remain. The ruins of two of the frontier forts established by the French in the early fur trading days may still be seen.

About twenty-five miles outside of Chicago on the north shore is located Fort Sheridan. The United States Naval Station at Great Lakes, Illinois, has a new \$10,000,000 naval training school, which is said to be the most completely equipped in the world.

The World's Columbian Exposition awakened the people of Chicago to a full appreciation of the esthetic needs of life and since that time its cultural progress as well as its industrial progress has been rapid and marked. One of the first evidences of this awakening was the organization of the Theodore Thomas Orchestra which resulted in the erection of Orchestra Hall by popular subscription. It seats 2500 people and is said to be the finest concert and recital hall in America. Other musical societies of fine reputation furnish good music and there are many music schools and colleges of high rank. In fact, it is said that Chicago has the largest musical college in the world. Summer opera at Ravinia Park is a delight and attracts many visitors.

One of the wonders of Chicago is its university whose assets now total around \$50,000,000. It comprises over 100 acres of land on which are situated more than 40 buildings. The large gifts of Stephen A. Douglas and J. D. Rockefeller have made this one of the greatest universities in this country.

Northwestern University is entitled to recognition for its work in making Chicago the educational center of the middle west. The university campus is located on the shore of Lake Michigan and has an area of about 75 acres.

Chicago has many large and splendid libraries. The public library at Michigan Boulevard and Washington Street is a magnificent building of Bedford limestone with granite base. The en-



trance from Washington Street is superbly impressive. Rare and beautiful marble is used in the decorations of the spacious stairway



Lincoln Memorial

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and balconies. It contains nearly a million books and periodicals for public use. The Blackstone, Newberry and Crerar libraries are beautiful structures and contain thousands of books and periodicals on every subject known to man.

Chicago is greatly indebted to the character, manhood and generosity of Marshall Field who taught the people of Chicago to



The Drake Hotel—Convention Headquarters

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think in terms of the world. It was he who brought new and interesting things from the far corners of the earth and it was largely through his efforts that Chicago has become "a city of the world."

And it is in this great city of Chicago that Eighth Annual National Steel and Machine Tool Exposition will be held the week of September 20, 1926. The huge Municipal Pier, 3000 feet in length has been entirely reserved for that week.

Last year in Cleveland 43,000 persons visited the exposition, while this year at Chicago 75,000 are expected.

Over 80,000 square feet of exhibit space have been reserved by exhibitors, and practically 75 per cent of the equipment will be shown in operation.

This steel exposition represents a complete cycle in the metal working and the metal treating industry. First, the steel from the raw material to the form in which it is bought, as shown by the steel manufacturers. Second, the machine tool section where manufacturers of machine tools will have their equipment in operation. And in order that this machinery and other produe-

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tion equipment may be in actual operation, it has necessitated the installing of sub-stations, capable of producing 5,000 horse power and the use of 25 miles of wire in order to properly distribute the electricity. These machine tools will be all hooked up and actually operating under factory and production conditions. Third, after the steel is fabricated, it will then be shown in the heat treating department, and all of the most important and up to date manufacturers of heat treating equipment and materials will have their products on display and in operation. Fourth, from the heat treating department the steel then goes to the inspection department, and inspection tools and equipment will be shown by numerous manufacturers.

Thus will be shown the complete cycle from the raw material to the finished product. No other exposition is so educational, so complete; no other exposition offers such an exceptional opportunity to see all the related lines in the metal working and metal treating industry.

CAMPBELL MEMORIAL LECTURE

Dr. Wm. Minot Guertler, Director of the "Metall-Institut der Technischen Hochschule," Berlin, Germany, has accepted the invitation of the Board of Directors to deliver the first E. D. Campbell Memorial lecture established in honor of the late Edward DeMille Campbell, for many years head of the Department of Chemistry at the University of Michigan, and an honorary member of the A. S. S. T.

Dr. Guertler has elected to present for the Campbell lecture a paper "*On the Corrosion-resistance of Steel.*" This will be presented at the close of the annual meeting on Wednesday morning, September 22nd. Dr. Guertler, being a recognized authority on both ferrous and non-ferrous metallurgy, from the practical and theoretical viewpoints, will also appear on the programs of Thursday and Friday. The Thursday paper will be entitled "*On the Light Metal Alloys,*" and on Friday he will present a lecture "*On the Hardness of Metals.*"

Dr. Guertler will remain in America for about eight weeks after the close of the Convention and will make guest appearances at educational institutions and before the various chapters of the A. S. S. T.

CONFERENCE ON METALLURGICAL EDUCATION

Metallurgical education has occupied a very important part in the deliberations of the A. S. S. T. Convention, due to the great interest of the members in the subject. At the Chicago Convention a luncheon meeting is scheduled for the Drake Hotel at 12:15 on Tuesday. This luncheon will close promptly at 1:50, in time for the afternoon technical sessions. The program will be divided into two parts; the metallurgical educational work by Educational Institutions, and metallurgical educational work by A. S. S. T. chapters. The Institute side of education will be presented by Prof. Bradley Stoughton, of Lehigh University, and the work of the chapters of the A. S. S. T. by President Bird. All interested are invited to attend.

HARDNESS SYMPOSIUM

The annual hardness symposium, under the direction of the Hardness Committee of the A. S. S. T. will be held in the ball room of the Drake Hotel on Friday, September 24, at 2:00 P. M.

The annual meeting of this committee is recognized as of great importance and the work to be presented this year will be of outstanding merit.

LADIES' ENTERTAINMENT

The Society has always worked on the policy that if the ladies have a good time, their escorts can take care of themselves. In other words, while your family wants to come to the Convention, they do not feel like coming if they are going to be a responsibility. So, the Ladies' Entertainment Committee, under the expert direction of Earl M. Converse, of the Dearborn Chemical Company, is going to relieve you of any responsibility you may feel for seeing that they have a good time. The headquarters for the ladies will be at the Drake Hotel.

The tentative schedule of events includes luncheons, drives, theatre parties, card parties, shopping tours and every other activity that is known to delight the hearts of the ladies.

MEN'S ENTERTAINMENT

Those who have attended the past seven Conventions of the A. S. S. T. realize that besides the wonderful score of technical sessions and the Exposition, the host chapter always arranges a series of entertainments having a tendency to add relaxation and enjoyment to educational progress. The Men's Entertainment

Committee, under the able direction of Ray Mau, of the Vanadium Alloy Steel Co., has arranged a schedule of entertainment which bids fair to go down in history as probably the most complete and enjoyable of any so far experienced.

The numerous country clubs around Chicago will be glad to receive the golf enthusiasts, so bring your clubs.

On Tuesday evening the formal dance will be held in the ball room of the Drake Hotel.

On Wednesday the annual smoker and frolic will be held at the Riding Academy. Ray Mau has made preparations to put on a real show and guarantees that it will be something out of the ordinary.

On Thursday evening the annual banquet will be held in the ball room of the Drake Hotel.

REGISTRATION

All registration of A. S. S. T. members, exhibitors and guests will be at Municipal Pier. Registration will begin Sunday morning at 10:00, so if you come into Chicago early, drop over and get your badge and relieve the congestion on Monday.

The Exposition will formally open at 12:00 noon, Monday. The first technical session will be held at the Drake at 10:00 a. m., Monday.

A. S. M. E. MEETING

The Machine Shop Practice Division of the American Society of Mechanical Engineers will hold a session during the annual Convention of the American Society for Steel Treating.

Due to the large exhibit of machine tools and the many members of the A. S. M. E. in attendance, a forum will be offered on this subject. The meeting will be held at the Drake hotel on either Thursday or Friday, September 23 or 24. The program arranged for that meeting is as follows:

Drop Forging Hammer Anvils—Eugene C. Clark, Chambersburg Engineering Co., Chambersburg, Penna.

The Possibilities of Standardizing Design Details in Plants Manufacturing Special Machinery—H. K. Keevir, McDonald Machine Co., Chicago.

Inspection Methods—E. D. Hall, Manufacturing Department, Western Electric Company, Hawthorne Plant, Chicago.

Foremanship Training—Hugo Diemer, LaSalle Extension Institute, Chicago.

S. A. E. PRODUCTION MEETING

During the annual Convention and National Steel Exposition to be held in Chicago the week of September 20th by the American Society for Steel Treating, the Society of Automotive Engineers is availing itself of the opportunity to meet in Chicago at the same time so that its members may have the privilege of attending not only their own programs but also the program of the A. S. S. T. and inspection of the big exposition to be held on Municipal Pier.

The Production Meeting of the Society of Automotive Engineers, with headquarters at Hotel Sherman, will be in session during this week on Tuesday, Wednesday and Thursday September 21, 22 and 23. There will be four technical sessions. Among the subjects to be discussed are the following:

Tuesday Morning, September 21

CONVEYOR SESSION. *Transportation by Conveyor*, by Paul Phelps and N. H. Preble, Mechanical Handling Systems, Inc. *Conveyors used in the Automotive Industry*, by Clarence A. Brock, Miller-Hust Corp.

Tuesday Afternoon, September 21

GEAR PRODUCTION SESSION. *Gear Steels and the Production of Automobile Gears*, by Walter G. Hildorf and John Bethune, Reo Motor Car Co. *Automobile Gear Construction*, by Charles L. Cameron, Gould and Eberhardt.

Tuesday Evening, September 21

The Stag Carnival,—Chez Pierre.

Wednesday Morning, September 22

INSPECTION SESSION. *Inspection Along the Line*, by A. H. Frauenthal, Chandler Motor Car Co. *Symposium on Special Devices for Automobile Inspection*,—A. R. Fors, Continental Motor Co.; P. W. Rhame, A. C. Spark Plug Co.; J. B. Scott, Yellow Sleeve Valve Engine Works; C. S. Stark, Packard Motor Car Co.; R. R. Todd, Oakland Motor Car Co.

Wednesday Afternoon, September 22

Inspection Visit to Nash Motors Co., Kenosha.

Thursday Morning, September 23

MACHINE TOOL SESSION. *What Goes Wrong with Machine Tools in Automobile Production*, by E. R. Stoddard, Studebaker Corp. *Fitting the Machine Tool to the Job*, by O. C. Kavle, Manufacturers' Consulting Engineers.

Thursday Afternoon, September 23

Inspection visits to International Harvester Company, and Yellow Truck

and Coach Manufacturing Company.

PLANT INSPECTION

The Plant Inspection Committee under the chairmanship of T. E. Barker has arranged a fine program of plant inspection trips. The trips and the hours of departure are given in the following pages.

Tuesday, September 21—Trip No. 1

To Harvey, Illinois. Will leave Randolph St. Station, Illinois Central Railroad at 9:00 A. M. Transportation will be at visitor's expense.

Party will visit the Buda Company, which is engaged in the manufacture of heavy duty motors for trucks, busses and taxicabs; heat treating, forging and foundry departments being of interest.

From the Buda Company, they will go to the Wyman-Gordon Company, a very modern drop forge plant, devoted principally to the manufacture of motor crank shafts.

"Wear Your Badge."

Tuesday, September 21—Trip No. 2

Miehle Printing Press and Manufacturing Company. Will leave Municipal Pier by street car at 1:00 P. M.; transportation at visitors' expense.

The visit to the Miehle Press and Manufacturing Company, which is one of the most modernly equipped metal treating and fabricating plants in the Chicago district, the following departments will be inspected: 1. Heat treating—rotary, special and oven furnaces; 2. Tool hardening department; 3. Screw machine department—automatic machine products of high accuracy; 4. Gear and cam-cutting department; 5. Drill press department—special drill presses of original design; 6. Cylinder turning and grinding department—production of large rolls to within extremely close limits; 7. Grinding department—cylindrical, internal, centerless and surface grinding; several machines of special design; 8. This plant is particularly noted for its jig, fixture and special tool equipment. This will be observed in the various departments.

"Wear Your Badge."

Tuesday, September 21—Trip No. 3

To American Forge Company and Tractor Works of International Harvester Company. Will leave Municipal Pier promptly at 1:00 P. M., in International Motor Coaches (product of International Harvester Co.).

Party will first visit the plant of the American Forge Company, the outstanding features of which are: the largest exclusive upset forge plant in the world. Present equipment consists of 18 upsetting machines, ranging from 2 inches to 6-7 inches, together with full equipment of heating and annealing furnaces, saws, trimmers, etc. Largest machines have a "gathering" capacity of approximately 115 pounds and are frequently producing forgings that weigh 350 pounds net.

A visit will then be made to the Tractor Works of the International Harvester Company, a large modern tractor and motor plant, some of the outstanding features of which are: modern forging practice on crank shafts and connecting rods; Mesta automatic pickling machines for forgings;

electric furnaces for hardening and drawing; bull gear drawing and shrinking furnaces; pusher type electric furnaces for annealing and hardening connecting rods; crank shaft and connecting rod machining and balancing equipment; gear cutting; tractor chassis assembly; tractor wheel manufacturing equipment; and motor assembling and testing.

Coaches will return with visitors to the Pier via Michigan Avenue, allowing those who wish to remain downtown the opportunity to get off without going to the Pier.

"Wear Your Badge."

Wednesday, September 22—Trip No. 4

To West Pullman Works of International Harvester Company. Will leave Municipal Pier promptly at 1:00 P. M. in International Motor coaches.

This plant is a very modern roller-bearing manufactory, its chief points of interest being: Storage of raw material; complete roller bearing manufacture, including: Forging of roller bearing cases; heat treating of roller bearing parts; modern type of gas-fired rotary hardening furnaces; Holcroft contra flow carburizing furnaces; latest type of equipment for machining, and grinding roller bearings; thorough roller bearing inspection; and bi-tension magneto manufacturing equipment.

Coaches will return with visitors to the Pier via Michigan Avenue, allowing those who wish to remain downtown an opportunity to get off without going to the Pier.

"Wear Your Badge."

Wednesday, September 22—Trip No. 5

To Indiana Harbor, Indiana. Will leave Municipal Pier at 9:00 A. M. by motor bus; transportation at visitors' expense.

Busses will be at the disposal of visitors all day, transferring them from plant to plant and returning them in the evening.

The first visit will be made to the Youngstown Sheet and Tube Company, where there will be exhibited the production of metallurgical coke and the processes by which the numerous so called by-products are recovered and refined; two of the largest and most modern blast furnaces receive coke, limestone and ore and deliver molten iron to Bessemer and open-hearth departments, where visitors may see both Bessemer and open-hearth steel reduced in ingot form. The soaking pits, blooming mill and billet mills are close at hand, as are also two smaller mills, reducing steel in plate form both for use in construction and for use in producing pipe therefrom. At the pipe mills may be seen all the operations connected with the welding of pipe in sizes from one-half inch diameter to 16 inches in diameter in both black and galvanized finishes. Those interested in the mechanical end may also see the most modern type of threading machine which is almost 100 per cent automatic and threads pipe approximately ten times faster than it can be threaded by the older type machines.

At the Inland Steel Company visitors will see a complete modern mill for the production of rails, bars and special shapes, together with a fabricating plant for the finishing of the same.

At the Standard Forgings Company will be seen a large, modern, well equipped plant, devoted to a general line of drop and steam hammer forg-

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ings, but devoted more particularly to railroad requirement, such as locomotive and car-building parts.

"Wear Your Badge."

Wednesday, September 22—Trip No. 6

To Pettibone Mulliken Company and Strom Bearings Company. Will leave Municipal Pier promptly at 1:00 P. M. by motor bus; transportation free.

Party will first visit plant of the Pettibone Mulliken Company where the features of interest will be electric furnace production of manganese steel, together with heat treatment and fabrication of the same. This plant is devoted to the production of heavy railway equipment, including frogs, crossings, switches, etc.

Visitors will next inspect the plant of the Strom Bearings Company, a large modern plant for the production of ball bearings of all types. Visitors will be shown the entire process, including forging, fabrication, heat treatment, inspection, etc.

"Wear Your Badge."

Thursday, September 23—Trip No. 7

To Western Electric Company. Will leave Municipal Pier at 1:00 P. M. by bus; transportation at visitors' expense.

The following departments of the Western Electric Company will be open to visitors: 1. Copper wire and rod mill; 2. Rubber plant; 3. Lead cable plant; 4. Tool making department; 5. Automatic machine switching demonstration laboratory.

"Wear Your Badge."

Thursday, September 23—Trip No. 8

To South Chicago. Will assemble at Randolph Street Station of Illinois Central Railroad to catch 9:20 train; transportation at visitors' expense.

This party will first be conducted through the plant of the Interstate Iron and Steel Company, where the manufacture and rolling of open-hearth alloy steel, bars and billets will be shown. From here, they will be conducted to the South Works of the Illinois Steel Company, where a luncheon will be served and a trip made through this plant which is devoted to the production of rails, shapes and plates by the open-hearth, electric and duplex processes.

"Wear Your Badge."

Thursday, September 23—Trip No. 9

To Pyrotung Manufacturing Company. Free bus transportation will be furnished, leaving the Pier at 10:00 A. M. An arrangement will also be made to pick up passengers at Madison and Michigan Blvd.

The following equipment will be open to visitors at the plant of the Pyrotung Manufacturing Company: twenty-one electric furnaces, including annealing, rotary carburizing, high speed, hardening, pre-heating, salt hardening pots, cyanide pots, oil and salt drawing baths; Centralized control equipment, including pyrometers, signal lights and control panels; Automatic temperature control on quenching mediums; refrigeration plant; laboratory, including latest type testing machines; grinding and polishing machines; metallographic equipment, etc., and forge and machine shop.

"Wear Your Badge."

Friday, September 24—Trip No. 10

To Burnside and Pullman. Will leave Randolph Street Station, Illinois Central Railroad, to catch train at 9:35 A. M.; transportation at visitors' expense.

This party will be conducted through the modern shops of the Illinois Central Railroad, thence to the plant of the Pullman Car Works, where will be shown the very interesting processes involved in the production of the modern railway palace cars.

"Wear Your Badge."

Friday, September 24—Trip No. 11

To Chicago Heights. Will leave Municipal Pier at 9:00 A. M.; free bus transportation both ways.

This party will visit first the works of the Columbia Tool Steel Company, a modern plant for the production of high grade tool steels, the crucible process being employed. Visitors will be taken through the rolling, forging, heat treating, roll turning and hammer die departments. Other features of interest will be their laboratories, metallographic equipment, hardness testing machines and apparatus for the determination of the cutting qualities of high speed steel tools. Luncheon will be served by this company at the conclusion of their plant inspection.

A trip will then be made through the works of the American Manganese Steel Company, which operates several Heroult electric melting furnaces, ranging from 6-ton capacity down, electric heat treating furnaces, together with such other equipment as is necessary for the production of manganese steel castings used in railroad track work, ditching machines, crushers, steam shovels, gears, etc.

"Wear Your Badge."

Friday, September 24—Trip No. 12

To A. Finkl & Sons Company and Aetna Ball Bearing Company. Will assemble at Municipal Pier at 9:30 A. M.; transportation by motor bus at visitors' expense.

At A. Finkl & Sons Company, there will be seen the production of die blocks for the drop forge trade and the production of heavy forgings for machinery builders; the equipment consisting of large hydraulic forging presses, steam hammers, special furnaces and quenching tanks for heat treating, and also large machine tools for rough machining forgings before shipment.

At the Aetna Ball Bearing Company, there is to be seen the manufacture of ball bearings by the cold forging process as well as machining from the bar. In their heat treatment department will be found rotary carburizing machines and automatic heat treating furnaces of the reciprocating hearth type. All furnaces are equipped with automatic temperature control. This plant is also equipped with the most modern grinding machinery, including large blanchard grinders, automatic internal grinders and special machinery for grinding race-ways.

"Wear Your Badge."

Friday, September 24—Trip No. 13

Armour Institute of Technology.

(Continued on Page 340)

CHAIR



T. E. L.
Plant



E. M.
Ladies



H. H.
Tra

CHAIRMEN OF CHICAGO CONVENTION COMMITTEES



T. E. BARKER
Plant Inspection



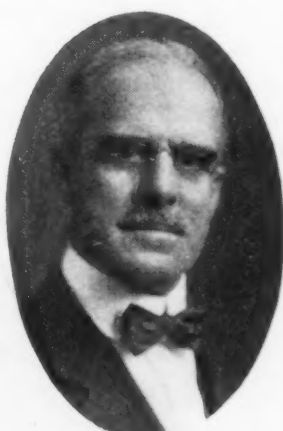
A. G. HENRY
General Secretary



S. M. HAVENS
Finance



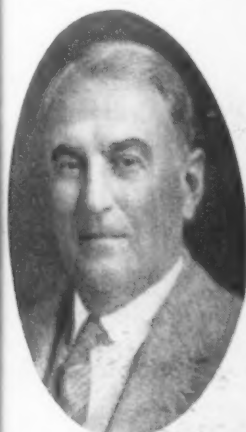
E. M. CONVERSE
Ladies' Entertainment



T. V. PURCELL
General Chairman



E. C. SMITH
Meetings and Papers



H. HARDWICKE
Transportation



W. E. WILLIAMS
Information



R. G. GUTHRIE
Vice-Chairman
Photographs by Wallinger



E. VON HAMBACH
Exposition



P. G. B. MORRIS
Hotels



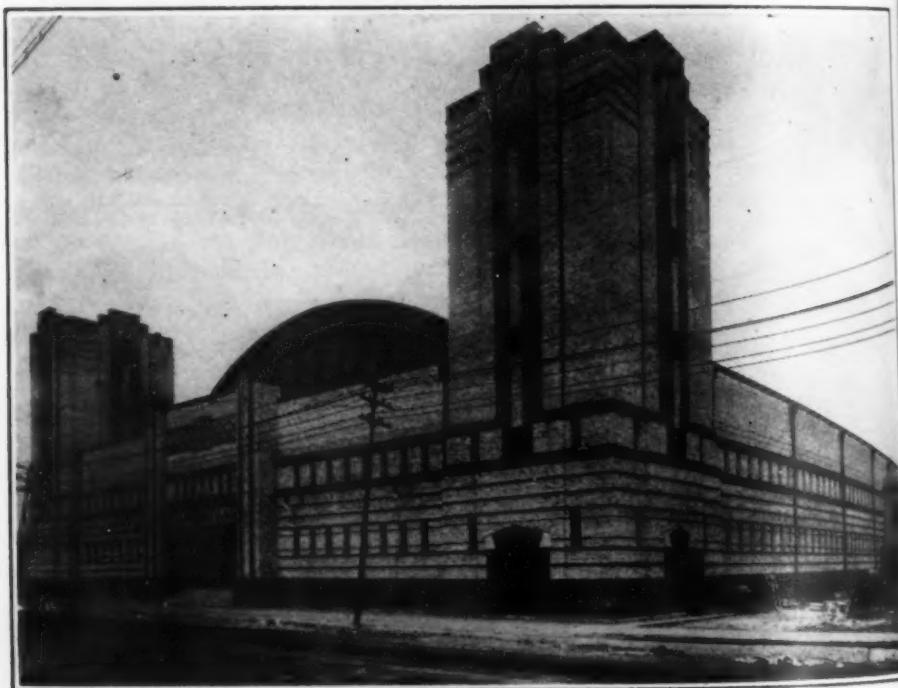
W. R. MAU
Men's Entertainment

Photographs by Wallace

This modern well equipped Institute of Technology will be open to visitors at all hours during the Convention.

Visitors desiring to make this trip will please consult the Information Bureau where arrangements will be made to suit their convenience.

Members and friends desiring to make any of the foregoing trips should make their arrangements at the Information Office as early as possible, and in no case less than two hours ahead of the time of departure.



Seventh Regiment Armory, Chicago, where the First Steel Exposition was held by the American Steel Treathers' Society in 1919

F. A. Arm
Moulte
H. A.

John Bie
C. P.
Cole,

F. G. W
P. A
C. V
Carh
E. J
C. F

Al. For
Dan

Mrs. W
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T. V. Purcell

GENERAL SECRETARY

A. G. Henry

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OUTLINE OF EVENTS
EIGHTH ANNUAL CONVENTION A. S. S. T.
EIGHTH ANNUAL STEEL AND MACHINE TOOL EXPOSITION
Chicago—Week of September 20th

All technical sessions, both morning and afternoon, will be held in the Ball Room of the Drake Hotel (Headquarters).

Monday, September 20

Exposition open from 12:00 M. to 10:00 P. M.

- 10:00 A. M.—Technical Session, Ball Room, Drake Hotel.
- 12:00 M. —Exposition Opens, Registration Begins, Municipal Pier.
- 2:00 P. M.—Technical Session, Ball Room, Drake Hotel.

Tuesday, September 21

Exposition open from 10:00 A. M. to 10:00 P. M.

- 9:00 A. M.—Plant Inspection.
- 9:30 A. M.—Technical Session, Drake Hotel.
- 10:00 A. M.—Exposition Opens.
- 12:15 P. M.—Metallurgical Educational Luncheon, Drake Hotel.
- 1:00 P. M.—Plant Inspection.
- 2:00 P. M.—Technical Session, Ball Room, Drake Hotel.
- 9:30 P. M.—Grand Ball, Ball Room, Drake Hotel.

Wednesday, September 22

Exposition open from 10:00 A. M. to 6:00 P. M.

- 9:00 A. M.—Plant Inspection.
- 9:30 A. M.—Annual Meeting of the A. S. S. T., Ball Room, Drake Hotel.
- 10:30 A. M.—E. D. Campbell Memorial Lecture, Ball Room, Drake Hotel.
- 1:00 P. M.—Plant Inspection.
- 2:00 P. M.—Technical Session, Ball Room, Drake Hotel.
- 6:00 P. M.—Exposition Closes for the Day.
- 9:30 P. M.—Smoker and Annual Frolic, Riding Academy.

Thursday, September 23

Exposition open from 10:00 A. M. to 6:00 P. M.

- 9:00 A. M.—Plant Inspection.
- 9:30 A. M.—Technical Session, Ball Room, Drake Hotel.
- 10:00 A. M.—Plant Inspection.
- 10:00 A. M.—Exposition Opens.
- 2:00 P. M.—Technical Session, Ball Room, Drake Hotel.
- 6:00 P. M.—Exposition Closes for the Day.
- 6:30 P. M.—Annual Banquet, Ball Room, Drake Hotel.

Friday, September 24

Exposition open from 10:00 A. M. to 10:00 P. M.

- 9:00 A. M.—Plant Inspection.
- 9:30 A. M.—Technical Session, Ball Room, Drake Hotel.
- 10:00 A. M.—Exposition Opens.
- 2:00 P. M.—Technical Session, Drake Hotel.
- 10:00 P. M.—Official Close of the Exposition.

TECHNICAL PAPERS PROGRAM, EIGHTH ANNUAL CONVENTION,
AMERICAN SOCIETY FOR STEEL TREATING, CHICAGO,
SEPTEMBER 20-24, 1926

MONDAY, SEPTEMBER 20

Meeting in Ball Room, Drake Hotel.

- 10:00 A. M.—Welcome by Chicago Chapter—T. E. Barker, Chairman.
Address of Welcome—T. V. Purell, General Chairman.
Response—President R. M. Bird.

Technical Session

Chairman—V. O. Homerberg.

- 10:15 A. M.—*The Importance of Cementite*—R. G. Guthrie, People's Gas Light and Coke Co., Chicago.
10:50 A. M.—*Electric Annealing of Magnetic Materials for Telephone Apparatus*—W. A. Timm, Western Electric Company, Chicago.
11:25 A. M.—*An Efficient Carburizing Furnace of the Surface Combustion Type*—Dr. A. E. White, University of Michigan, Ann Arbor, Michigan, and E. R. McPherson, Packard Motor Car Co., Detroit.

Afternoon Session

- 12:00 M. —Exposition Opens.
2:00 P. M.—Technical Session—Ball Room, Drake Hotel.
Chairman—H. M. Boylston.
2:00 P. M.—*Observations on the Microstructure of Path of Fatigue Failure in a Specimen of Armco Iron*—F. F. Lucas, Bell Telephone Laboratories, New York City.
2:40 P. M.—*Fatigue Strength of Hard Steels and Their Relation to Tensile Strength*—J. M. Lessells, Westinghouse Electric and Manufacturing Company, East Pittsburgh.
3:20 P. M.—*Corrosion-Fatigue of Metals as Affected by Chemical Composition, Heat Treatment and Cold-Working*—Dr. D. J. McAdam, Jr., United States Naval Academy, Engineering Experiment Station, Annapolis, Md.
4:00 P. M.—*High Speed Steels*—F. C. A. H. Lantsberry, Wm. Jessop & Sons, Ltd., Brightside Works, Sheffield, England.

Evening Session

Exposition open until 10:00 P. M.

TUESDAY, SEPTEMBER 21

Morning Session

Meeting in Ball Room, Drake Hotel.

Chairman—W. J. Priestley.

- 9:00 A. M.—Plant Inspection.
9:30 A. M.—STEEL MELTING SESSION.
9:30 A. M.—*Hair Cracks in Steel Rails*—J. H. Whitley, South Durham Steel and Iron Company, Ltd., Malleable Works, Stockton-on-Tees, England.
9:50 A. M.—*Solidification of Steel in the Ingot Mold*—Alex L. Feild, United Alloy Steel Corporation, Canton, Ohio.
10:30 A. M.—*Desulphurization of Steel*—E. J. Lowry, Hickman, Williams Company, Chicago.
11:15 A. M.—*Basic Open-Hearth Practice*—C. H. Herty, Jr., Bureau of Mines Experiment Station, United States Department of Commerce, Pittsburgh.
10:00 A. M.—Exposition Opens.

Afternoon Session

- 1:00 P. M.—Plant Inspection.
2:00 P. M.—Technical Session—Ball Room, Drake Hotel.
Chairman—T. D. Lynch.

- 2:00 P. M.—*Notes on the A_3 Stable Transformation*—H. A. Schwartz, National Malleable and Steel Castings Company, Cleveland.
- 2:20 P. M.—*Graphitization at Constant Temperature Below the Critical Point*—H. A. Schwartz and H. H. Johnson, National Malleable and Steel Castings Company, Cleveland.
- 2:40 P. M.—*The Graphitizing Behavior of Iron Carbide in Pure Iron-Carbon Alloys in the Critical Range*—H. P. Evans and Anson Hayes, Iowa State College, Ames, Iowa.
- 3:20 P. M.—*Mechanical and Machining Properties of an Annealed Cast Iron*—G. C. Priester and F. J. Curran. G. C. Priester, University of Minnesota, Minneapolis.
- 9:30 P. M.—Gand Ball, Ball Room, Drake Hotel.

WEDNESDAY, SEPTEMBER 22**Morning Session**

- 9:00 A. M.—Plant Inspection.
- 9:30 A. M.—ANNUAL MEETING OF THE AMERICAN SOCIETY FOR STEEL TREATING.—Ball Room, Drake Hotel.
Chairman—R. M. Bird.
Report of Chapter Delegates.
Report of Officers.

Technical Session

- Chairman—Dr. A. E. White.
- 10:30 A. M.—E. D. Campbell, Memorial Lecture.
On the Corrosion-Resistance of Steels—Dr. William M. Guertler, Germany.
- 11:15 A. M.—*The Iron-Molybdenum System*—W. P. Sykes, General Electric Company, Cleveland.
- 10:00 A. M.—Exposition Opens.

Afternoon Session

- 1:00 P. M.—Plant Inspection.
- 2:00 P. M.—Technical Session.—Ball Room, Drake Hotel.
Chairman—F. P. Gilligan.
- 2:00 P. M.—*Cyanide Brittleness*—V. E. Hillman and E. D. Clark, Crompton and Knowles Loom Works, Worcester, Mass.
- 2:30 P. M.—*Wear Resistance of Carburized Steel Versus Cast High Manganese Steel*—W. J. Merten, Westinghouse Electric and Manufacturing Company, East Pittsburgh.
- 3:00 P. M.—*Wear of Steels with Particular Reference to Plug Gages*—H. J. French and H. K. Herschman, Bureau of Standards, Department of Commerce, Washington, D. C.
- 3:30 P. M.—*Studies on Electric Welding*—L. J. Weber, University of Minnesota, Minneapolis.
- 6:00 P. M.—Exposition Closes for the Day.

Evening Session

- 9:30 P. M.—Smoker and Annual Frolic, Riding Academy.

THURSDAY, SEPTEMBER 23**Morning Session**

- 9:20 A. M.—Plant Inspection.
- 9:30 A. M.—Technical Session.—Ball Room, Drake Hotel.
Chairman—Dr. Albert Sauveur.
- 9:30 A. M.—*On the Transformation of Retained Austenite into Martensite by Stress*—Dr. Kotaro Honda and Keizo Iwase, Tohoku Imperial University, Sendai, Japan.
- 9:50 A. M.—*The Nature of Oil-Hardening Non-Deforming Tool Steels*—E. C. Bain and M. A. Grossmann. E. C. Bain, Union Carbide and Carbon Research Laboratories, Inc., New York City. M. A. Grossmann, United Alloy Steel Company, Canton, Ohio.

- 10:30 A. M.—*The Hardening of Metals by Dispersed Constituents Precipitated from Solid Solutions*—R. S. Archer, Aluminum Company of America, Cleveland.
- 11:10 A. M.—*Investigation of the Relationship Between the Standard Tension and Impact Tests on a Group of Steels of Varying Compositions*—Dr. F. C. Langenberg and H. C. Mann, Watertown Arsenal, Watertown, Mass.
- 10:00 A. M.—Exposition Opens.
- 10:00 A. M.—Plant Inspection.

Afternoon Session

- 1:00 P. M.—Plant Inspection.
- 2:00 P. M.—Technical Session—Ball Room, Drake Hotel.
Chairman—Dr. George K. Burgess.
- 2:00 P. M.—*The Decomposition of the Austenitic Structure in Steels*—Dr. R. L. Dowdell and Dr. O. E. Harder, University of Minnesota, Minneapolis, Minn.
- 2:40 P. M.—*On the Light Metal Alloys*—Dr. William M. Guertler, Germany.
- 3:20 P. M.—*The Tensile Properties of Stainless Iron and Other Alloys at Elevated Temperatures*—P. G. McVetty and N. D. Mochel, Westinghouse Electric and Manufacturing Company, East Pittsburgh.
- 6:00 P. M.—Exposition closes for the day.

Evening Session

- 6:30 P. M.—Annual Banquet of the A. S. S. T.—Ball Room, Drake Hotel.

FRIDAY, SEPTEMBER 24**Morning Session**

- 9:00 A. M.—Plant Inspection.
- 9:30 A. M.—Technical Session—Ball Room, Drake Hotel.
Chairman—Bradley Stoughton.
- 9:30 A. M.—*Investigation of Bolt Steels*—V. T. Malcolm, The Chapman Valve Manufacturing Company, Indian Orchard, Mass.
- 10:00 A. M.—*Internal Stresses in Quenched Steel*—Dr. S. L. Hoyt, General Electric Company, Schenectady, N. Y.
- 10:40 A. M.—*Aluminum Bronze*—Jerome Strauss, U. S. Naval Gun Factory, Navy Yard, Washington, D. C.
- 11:15 A. M.—*New Process of Surface Hardening Special Steels*—T. H. Nelson, Ludlum Steel Company, Watervliet, N. Y.
- Dendritic Crystallization and Grain Formation in Steels*—Dr. V. N. Krivobok, Bureau of Metallurgical Research, Carnegie Institute of Technology, Pittsburgh. (By title).
- 10:00 A. M.—Exposition Opens.

Afternoon Session

- 2:00 P. M.—SYMPOSIUM OF HARDNESS TESTING COMMITTEE OF THE A. S. S. T.—Ball Room, Drake Hotel.
Chairman—Dr. H. P. Hollnagel
- 2:00 P. M.—*Standardizing the Brinell Hardness Test*—H. M. German, Universal Steel Company, Bridgeville, Pa.
- 2:20 P. M.—*On the Hardness of Metals*—Dr. William M. Guertler, Germany.
- 3:10 P. M.—*Correlation of Magnetic Properties with Mechanical Hardness in Cold-Worked Metals*—S. R. Williams, Amherst College, Amherst, Mass.
- 3:40 P. M.—*Hardness Testing of Steel Balls by Magnetic Methods*—S. R. Williams, Amherst College, Amherst, Mass.
- 4:10 P. M.—*Additional Notes on the Hardness and Toughness of High Speed Steel*—Robert K. Barry, Barry Co., Muscatine, Iowa.
- 10:00 P. M.—Exposition Officially Closes.

LIST OF EXHIBITORS

ON the following pages is the list of exhibitors who will exhibit at the Eighth Annual Steel and Machine Tool Exposition of the A. S. S. T., Municipal Pier, Chicago, September 20-24, 1926.

A

A
E

Abrasive Machine Tool Company
Acme Machine Tool Company
Adams & Son, George
Air Reduction Sales Company
Ajax Manufacturing Company
Allegheny Steel Company
Allen, Chas. G.
Allis-Chalmers Manufacturing Company
Alto Manufacturing Company
American Crusher & Machinery Corporation
American Cyanamid Company
American Gas Association
American Gas Furnace Company
American Machinist
American Metallurgical Corporation
American Resistor Company
American Stainless Steel Company
American Tool Works Company
American Twist Drill & Tool Company
Ames Company, B. C.
Anderson Die Machine Company
Andresen and Associates, Incorporated, F. C.
Armstrong-Blum Manufacturing Company
Armstrong Bros. Tool Company
Armstrong Cork & Insulation Company
Atkins & Company, E. C.
Atlas Press Company
Atlas Steel Corporation
Avey Drilling Machine Company

East Providence, R. I.
Cincinnati
Chicago
New York City
Cleveland
Brackenridge, Pa.
Barre, Mass.
East Allis, Wis.
Chicago
New York City
New York City
New York City
Elizabeth, N. J.
New York City
Boston
Milwaukee
Pittsburgh
Cincinnati
Detroit
Waltham, Mass.
Bridgeport, Conn.
Pittsburgh
Chicago
Chicago
Pittsburgh
Indianapolis
Kalamazoo, Mich.
Dunkirk, N. Y.
Cincinnati

B

Badger Tool Company
Baker Brothers
Baker-Raulang Company
Barber-Colman Company
Bardons & Oliver
Barnes Co., W. F. & John
Barnes Drill Company
Barrett Company, Leon J.
Bartlett, Edwin E.
Bath & Co., John
Bausch & Lomb Optical Company
Bearium Bearings, Incorporated
Bell & Gossett Company
Bellevue Industrial Furnace Company
Bellis Heat Treating Company
Best Corporation, W. N.
Bethel-Player Company
Bethlehem Steel Company, Incorporated
Billings & Spencer Company
Bilton Machine Tool Company
Black & Decker Manufacturing Company

Beloit, Wis.
Toledo, Ohio
Cleveland
Rockford, Ill.
Cleveland
Rockford, Ill.
Rockford, Ill.
Worcester, Mass.
Nashua, N. H.
Worcester, Mass.
Rochester, N. Y.
Buffalo
Chicago
Detroit
Branford, Conn.
New York City
Westboro, Mass.
Bethlehem, Pa.
Hartford
Bridgeport, Conn.
Towson, Md.

Blacker Engineering Company
 Blake & Johnson Company
 Blakeslee & Company, G. S.
 Blanchard Machine Company
 Botfield Refractories Company
 Boyle Valve Company
 Bridgeport Safety Emery Wheel Company
 Bristol Company
 Brown Boiler Company of Illinois, John
 Brown & Company, D. P.
 Brown Instrument Company
 Brown Lynch Scott Company
 Brown & Sharpe Manufacturing Company
 Bryant Chucking Grinder Company
 Buckeye Portable Tool Company
 Buffalo Forge Company
 Bullard Machine Tool Company

C

Calorizing Company, The
 Campbell, Incorporated, Andrew C.
 Carborundum Company (Refractories)
 Carborundum Company (Abrasives)
 Carlton Machine Tool Company
 Carpenter Steel Company
 Case Hardening Service Company
 Celite Products Company
 Central Steel Company
 Chambersburg Engineering Company
 Chapin Company, W. R.
 Char Products Company
 Chicago Pneumatic Tool Company
 Cincinnati Bickford Tool Company
 Cincinnati Milling Machine Company
 Cincinnati Planer Company
 Cincinnati Shaper Company
 Clark Equipment Company
 Clark, Jr., Electric Company, James
 Clark Tractor Company
 Cleveland Automatic Machine Company
 Cleveland Planer Company
 Cleveland Twist Drill Company
 Climax Molybdenum Company
 Clipper Belt Lacer Company
 Cochrane-Bly Company
 Colonial Steel Company
 Colonial Tool Company
 Cone Automatic Machine Company
 Consolidated Machine Tool Corporation
 Colburn Machine Tool Company
 Colt's Patent Fire Arms Manufacturing Company
 Columbia Tool Steel Company
 Cooper Hewitt Electric Company
 Crankshaft Machine Company
 Crucible Steel Company of America
 Cushman Chuck Company

New York City
 Waterbury, Conn.
 Chicago
 Cambridge, Mass.
 Philadelphia
 Chicago
 Bridgeport, Conn.
 Waterbury, Conn.
 St. Louis
 Detroit
 Philadelphia
 Monmouth, Ill.
 Providence, R. I.
 Springfield, Vt.
 Dayton, Ohio
 Buffalo
 Bridgeport, Conn.

Pittsburgh
 Bridgeport, Conn.
 Perth Amboy, N. J.
 Niagara Falls, N. Y.
 Cincinnati
 Reading, Pa.
 Cleveland
 Los Angeles
 Massillon, Ohio
 Chambersburg, Pa.
 Indianapolis
 Indianapolis
 Chicago
 Cincinnati
 Cincinnati
 Cincinnati
 Cincinnati
 Buchanan, Mich.
 Louisville, Ky.
 Buchanan, Mich.
 Cleveland
 Cleveland
 Cleveland
 New York City
 Grand Rapids, Mich.
 Rochester, N. Y.
 Pittsburgh
 Detroit
 Springfield, Vt.
 Rochester, N. Y.
 Rochester, N. Y.
 Hartford
 Chicago Heights, Ill.
 Hoboken, N. J.
 Jackson, Mich.
 New York City
 Chicago

D

Danly Machine Specialties, Incorporated	Chicago
Darwin & Milner Company	Cleveland
Davis Boring Tool Company	St. Louis
Davison Gas Burner & Welding Company, N. C.	Pittsburgh
Dearborn Chemical Company	Chicago
Diamond Machine Company	Providence, R. I.
Disston & Sons, Incorporated, Henry	Philadelphia
Dixon Company, H. L.	Pittsburgh
Donner Steel Company	Buffalo
Dreses Machine Tool Company	Cincinnati
Driver-Harris Company	Harrison, N. J.
Duriron Company, Incorporated	Dayton, Ohio
Drying Systems, Incorporated	Chicago

E

Eaton Electric Furnace Company	Taunton, Mass.
Eclipse Fuel Engineering Company	Rockford, Ill.
Edlund Machinery Company, Incorporated	Cortland, N. Y.
Electric Furnace Company	Salem, Ohio
Electrical Refractories Company	East Palestine, Ohio
Electro Alloys Company	Elyria, Ohio
Ellis Engineering Company, R. E.	Chicago
Emerman & Company, Louis E.	Chicago
Endicott Forging & Manufacturing Company, Inc.	Endicott, N. Y.
Engelhard, Incorporated, Chas.	New York City
Equipment Manufacturing Company	Worcester, Mass.
Essley Machinery Company, E. L.	Chicago
Ex-Cell-O Tool & Manufacturing Company	Detroit

F

Fairbanks-Morse Company	Chicago
Federal Press Company	Elkhart, Ind.
Federal Machinery Sales Company	Chicago
Ferner Company, R. Y.	Washington, D. C.
Ferry Cap & Set Screw Company	Cleveland
Finkl & Sons Company, A.	Chicago
Firth-Sterling Steel Company	McKeesport, Pa.
Fitchburg Grinding Machine Company	Fitchburg, Mass.
Flather Company	Nashua, N. H.
Foote Bros. Gear & Machine Company	Chicago
Ford Company, J. B.	Wyandotte, Mich.
Foote-Burt Company	Cleveland
Forging-Stamping-Heat Treating	Pittsburgh
Foster Machine Company	Elkhart, Ind.
Fox Machine Company	Jackson, Mich.

G

Gairing Tool Company, Incorporated	Detroit
Gallmeyer & Livingston Company	Grand Rapids, Mich.
Gammons Holman Company	Manchester, Conn.
Gardner Machine Company	Beloit, Wis.
Gateman Manufacturing Company, W.	Manitowoc, Wis.
Gathmann Engineering Company	Baltimore, Md.
General Alloys Company	Boston
General Electric Company	Schenectady, N. Y.
Geometric Tool Company	New Haven, Conn.
Gibson Company, Wm. D.	Chicago
Giddings & Lewis Machine Tool Company	Fond du Lac, Wis.
Gilbert & Barker Manufacturing Company	Springfield, Mass.

Gilbert G.
Gisholt M.
Gits Bros.
Goddard
Gordon C.
Goss & d
Gould &
Gray Co
Greenfield

Hagan C.
Halcomb
Hall-Wil
Hammon
Hand E.
Hanson-
Heald M.
Heat Tr
Heim G.
Heppens
Hevi D.
High P.
High Sp
Hoefler
Holcrof
Hoover
Hoskins
Hought

Illinois
Intern
Intern
Intersta
Iron A
Iron T

Jarvis
Jessop
Jones
Jones

Kane
Kearn
Keller
Kelly
Kemp
Keyst
King
Kings
Klost
Knigh
Kropf

Land
Land
La S

Gilbert Grinder Company, J. E.
 Gisholt Machine Company
 Gits Bros. Manufacturing Company
 Goddard & Goddard Company
 Gordon Company, Claud S.
 Goss & deLeeuw Machine Company
 Gould & Eberhardt
 Gray Company, G. A.
 Greenfield Tap & Die Corporation

H

Hagan Company, George J.
 Halcomb Steel Company
 Hall-Will, Incorporated
 Hammond Manufacturing Company
 Hande Wrench Sales Company
 Hanson-Whitney Machine Company
 Heald Machine Company
 Heat Treating Supply Company
 Heim Grinder Company
 Heppenstall Forge & Knife Company
 Hevi Duty Electric Company
 High Power Tool Corporation
 High Speed Hammer Company
 Hoefer Manufacturing Company
 Holcroft & Company
 Hoover Steel Ball Company
 Hoskins Manufacturing Company
 Houghton & Company, E. F.

I

Illinois Tool Works
 International Machine Tool Company
 International Nickel Company
 Interstate Iron and Steel Company
 Iron Age
 Iron Trade Review

J

Jarvis Company, Chas. L.
 Jessop Steel Company
 Jones & Lamson Machine Company
 Jones & Laughlin Steel Corporation

K

Kane & Roach
 Kearney & Trecker Company
 Keller Mechanical Engineering Corporation
 Kelly Reamer Company
 Kemp Smith Manufacturing Company
 Keystone Lubricating Company
 King Refractories Company, Incorporated
 Kingsbury Machine Company
 Kloster Steel Corporation
 Knight Machinery Company, W. B.
 Kropp Forge Company

L

Landis Machine Company
 Landis Tool Company
 La Salle Tool Company

Milwaukee
 Madison, Wis.
 Chicago
 Detroit
 Chicago
 New Britain, Conn.
 Newark, N. J.
 Cincinnati
 Greenfield, Mass.

Pittsburgh
 Syracuse, N. Y.
 Erie, Pa.
 Cleveland
 Chicago
 Hartford
 Worcester, Mass.
 Sandusky, Ohio
 Danbury, Conn.
 Pittsburgh
 Milwaukee
 Jackson, Mich.
 Rochester, N. Y.
 Freeport, Ill.
 Detroit
 Ann Arbor, Mich.
 Detroit
 Philadelphia

Chicago
 Indianapolis
 New York City
 Chicago
 New York City
 Cleveland

Gildersleeve, Conn.
 Washington, Pa.
 Springfield, Vt.
 Pittsburgh

Syracuse, N. Y.
 Milwaukee
 Brooklyn, N. Y.
 Cleveland
 Milwaukee
 Philadelphia
 Buffalo
 Keene, N. H.
 Chicago
 St. Louis
 Chicago

Waynesboro, Pa.
 Waynesboro, Pa.
 La Salle, Ill.

LeBlond Machine Tool Company, R. K.
 Leeds & Northrup Company
 Lehmann Machine Company
 Leitz, Incorporated, E.
 Leland Gifford Company
 Liberty Machine Tool Company
 Lindberg Steel Treating Company
 Link Belt Company
 Lodge & Shipley Machine Tool Company
 Logansport Machine Company
 Loshbough-Jordan Tool & Machine Company
 Ludlum Steel Company

Cincinnati
 Philadelphia
 St. Louis
 New York City
 Worcester, Mass.
 Hamilton, Ohio
 Chicago
 Chicago
 Cincinnati
 Logansport, Ind.
 Elkhart, Ind.
 Watervliet, N. Y.

M

Machinery
 Mackintosh-Hemphill Company
 Madison-Kipp Corporation
 Mahr Manufacturing Company
 Manning, Maxwell & Moore, Incorporated
 Marshall & Huschart Machinery Company
 McCrosky Tool Corporation
 McGill Metal Company
 Metalwood Manufacturing Company
 Michigan Tool Company
 Micro Machine Company
 Midvale Company
 Modern Grinder Company
 Moline Tool Company
 Molybdenum Corporation of America
 Monarch Machine Tool Company
 Morse Twist Drill & Machine Company
 Morton Manufacturing Company
 Murchey Machine & Tool Company

New York City
 Pittsburgh
 Madison, Wis.
 Indianapolis
 Chicago
 Chicago
 Meadville, Pa.
 Valparaiso, Ind.
 Detroit
 Detroit
 Bettendorf, Iowa
 Nicetown, Philadelphia
 Erie, Pa.
 Moline, Ill.
 Pittsburgh
 Sidney, Ohio
 New Bedford, Mass.
 Muskegan Hts., Mich.
 Detroit

N

National Acme Company
 National Automatic Tool Company
 National Electric Light Association
 National Machinery Company
 National Twist Drill & Tool Company
 Nazel Engineering & Machine Works
 Neff Kohlbusch & Bissell, Incorporated
 New Britain Machine Company
 Niagara Machine & Tool Works
 Niles-Bement-Pond Company
 Niles Tool Works
 Norton Company (Abrasive)
 Norton Company (Machinery)
 Nuttall Company, R. D.

Cleveland
 Richmond, Ind.
 Chicago
 Tiffin, Ohio
 Detroit
 Philadelphia
 Chicago
 New Britain, Conn.
 Buffalo
 New York City
 Hamilton, Ohio
 Worcester, Mass.
 New York City
 Pittsburgh

O

Oesterlein Machine Company
 Ohio Machine Tool Company
 Ohio Steel Foundry Company
 Oilgear Company
 O. K. Tool Company, Incorporated
 Oliver Instrument Company
 Olsen Testing Machine Company, Tinius
 Oxweld Acetylene Company

Cincinnati
 Kenton, Ohio
 Lima, Ohio
 Milwaukee
 Shelton, Conn.
 Adrian, Mich.
 Philadelphia
 New York City

Park Ch
 Peerless
 Pels & C
 People's
 Perfection
 Pittsburgh
 Plibrico
 Potter &
 Pratt &
 Precision
 Producti
 Pyrotun

Racine
 Rahn-L
 Rand K
 Reed-P
 Reeves
 Republic
 Rivett
 Rockwe
 Rockwe
 Rodma
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Safety
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 Shore
 Sidney
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 SKF
 Skybr
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 Smith
 Smith
 South
 Spenc
 Stand
 Stand
 Stand
 Starr
 Steel
 Stocl
 Stocl
 Stran
 Stua
 Sun
 Sun
 Surf
 Swe
 Swe

P

Park Chemical Company
 Peerless Machine Company
 Pels & Company, Incorporated, Henry
 People's Gas Light & Coke Company
 Perfection Tool Hardening Company
 Pittsburgh Instrument & Machine Company
 Plibrico Jointless Firebrick Company
 Potter & Johnston Machine Company
 Pratt & Whitney Company
 Precision Truing Machine & Tool Company
 Production Machine Company
 Pyrotung Manufacturing Company

R

Racine Tool & Machine Company
 Rahn-Larmon Company
 Rand Kardex Service Corporation
 Reed-Prentice Company
 Reeves Pulley Company
 Republic Flow Meters Company
 Rivett Lathe & Grinder Corporation
 Rockwell Company, Stanley P.
 Rockwell Company, W. S.
 Rodman Chemical Company
 Roessler & Hasslacher Chemical Company
 Ruemelin Manufacturing Company
 Ryerson Company, Joseph T.

S

Safety Emery Wheel Company
 Scherr Company, George
 Sebastian Lathe Company
 Seneca Falls Machine Company
 Shore Instrument & Manufacturing Company
 Sidney Machine Tool Company
 Simonds Saw & Steel Company
 SKF Industries, Incorporated
 Skybryte Company
 Sleeper & Hartley, Incorporated
 Smith & Mills Company
 Smith & Son, David H.
 Southern Manganese Steel Company
 Spencer Turbine Company
 Standard Fuel Engineering Company
 Standard Steel Specialties Company
 Standard Tool Company
 Starrett Company, L. S.
 Steel City Testing Laboratory
 Stockbridge Machine Company
 Stocker-Rumely-Wachs Company
 Strand & Company, N. A.
 Stuart & Company, D. A.
 Sun Oil Company
 Sundstrand Machine Tool Company
 Surface Combustion Company
 Swedish Crucible Steel Company
 Swedish Iron & Steel Corporation

Detroit
 Racine, Wis.
 New York City
 Chicago
 Chicago
 Pittsburgh
 Chicago
 Pawtucket, R. I.
 Hartford
 Cincinnati
 Worcester, Mass.
 Chicago

Racine, Wis.
 Cincinnati
 Tonawanda, N. Y.
 Worcester, Mass.
 Columbus, Ind.
 Chicago
 Boston
 Hartford
 New York City
 Verona, Pa.
 New York City
 Minneapolis
 Chicago

Springfield, Ohio
 New York City
 Cincinnati
 Seneca Falls, N. Y.
 Jamaica, N. Y.
 Sidney, Ohio
 Lockport, N. Y.
 New York City
 Cleveland
 Worcester, Mass.
 Cincinnati
 Brooklyn, N. Y.
 St. Louis
 Hartford
 Detroit
 Beaver Falls, Pa.
 Cleveland
 Athol, Mass.
 Detroit
 Worcester, Mass.
 Chicago
 Chicago
 Chicago
 Philadelphia
 Rockford, Ill.
 New York City
 Detroit
 Brooklyn, N. Y.

T

Taylor Instrument Company
Thompson Company, Henry G.
Thompson Grinder Company
Timken Roller Bearing Company

U

Union Drawn Steel Company
Union Electric Steel Corporation
Union Manufacturing Company
Union Twist Drill Company
Unishear Company, Incorporated
United Alloy Steel Corporation
United States Electric Tool Company
Universal Boring Machine Company
Universal Grinding Machine Company
Universal Steel Company

V

Vacuum Belting Company
Vanadium-Alloys Steel Company
Van Dorn Electric Tool Company
Van Norman Machine Tool Company
V & O Press Company
Vulcan Crucible Steel Company
Vulcan Mold & Iron Company

W

Walcott Machine Company
Walker Company, O. S.
Wappler Electric Company, Incorporated
Warner & Swasey Company
Western Bearings Company
Westinghouse Electric & Manufacturing Company
Wheelock, Lovejoy & Company, Incorporated
Whitney Manufacturing Company
Whitney Metal Tool Company
Wilsey-Tuthill Pumps
Whipp Machine Tool Company
Wilmarth & Morman Company
Wilson-Maeulen Company
Wisconsin Electric Company, Incorporated

Z

Zeh & Hahnemann Company
Ziv Steel & Wire Company

Rochester, N. Y.
New Haven, Conn.
Springfield, Ohio
Canton, Ohio

Beaver Falls, Pa.
Pittsburgh
New Britain, Conn.
Athol, Mass.
New York City
Canton, Ohio
Cincinnati
Hudson, Mass.
Fitchburg, Mass.
Bridgeville, Pa.

Indianapolis
Latrobe, Pa.
Cleveland
Springfield, Mass.
Hudson, N. Y.
Aliquippa, Pa.
Latrobe, Pa.

Jackson, Mich.
Worcester, Mass.
Long Island City
Cleveland
Chicago
East Pittsburgh
Boston
Hartford
Rockford, Ill.
Chicago
Sidney, Ohio
Grand Rapids, Mich.
New York City
Racine, Wis.

Newark, N. J.
Chicago

ARMY ORDNANCE MEETING

IN the August issue of TRANSACTIONS was published the resolution adopted by the Board of Directors of the Army Ordnance Association in which a cordial invitation was extended to the members of the American Society for Steel Treating to attend the Eighth Annual Meeting of the Army Ordnance Association which will be held at Aberdeen Proving Ground, Maryland, October 8, 1926.

While no new information regarding the program of events have been received since our August issue we are sure that the program will be of great interest. Remember the date, October 8, 1926.

STAINLESS IRON

By N. L. MOCHEL

Abstract

This paper discusses the characteristics of low-carbon chromium-iron alloys known commercially as "stainless iron." Data is given relative to physical properties of alloys of varying composition and with varying heat treatment. Especial attention is directed to elastic limit and impact values. The effect of varying chromium content, and of silicon, copper and nickel, on the physical properties, microstructure, resistance to corrosion and workability of the alloys is discussed.

INTRODUCTION

THIS paper refers to an investigation dealing with "stainless iron." Data and information are given which are drawn from actual experience with numerous lots of material from several suppliers and from a considerable quantity of material. The work covered is a part of the investigation at the South Philadelphia Works of the Westinghouse Electric and Manufacturing Company, of all types of corrosion-resistant materials, and especially a part of the study of so-called stainless iron, which study has been in progress during the past several years.

The paper deals with a group of chromium-iron alloys, having a carbon content of not over 0.12 per cent and a chromium content of approximately 10 to 19 per cent. Alloys are included which come within the above carbon and chromium limits, which, in addition, contain silicon in excess of that usually found, and copper and nickel. The paper, however, will be limited entirely to the low carbon alloys, of the stainless iron type.

MATERIALS TESTED

The materials used were in all cases hot-rolled and annealed bars when received. Some were sample bars, others were small trial lots of special rollings, while others were from fairly large quantities which would readily come within the field of commercial production. From the many lots examined and tested, fifteen

A paper presented before the Philadelphia Chapter, the Lehigh Valley Chapter, and the Spring Sectional Meeting at Hartford, May, 1926.

The author, N. L. Mochel, is metallurgical engineer, Westinghouse Electric and Manufacturing Company, South Philadelphia.

have been selected as best representing the chemical ranges given above. One steel was of English manufacture, one of Swedish, and the remainder produced by American manufacturers. The American steels were produced in the electric furnace.

TESTS MADE

The investigation had originally and primarily to do with high grade drop forgings of these materials, and the plan was followed in all cases to forge the bars to $\frac{7}{8}$ inches square or round, and to carry out the subsequent heat treating and testing on these forged specimens.

Tension tests at room temperature were made on the usual 0.505-inch diameter by 2 inch gage length threaded specimens, in a 100,000-pound universal testing machine. Tension tests at elevated temperatures were made following methods already described (1)¹. Brinell tests were made with 3000-kilogram load and a 10-millimeter ball. Impact tests were made on 0.394-inch square and 0.450-inch round notched specimens, in a 120-foot pound Izod machine. Endurance tests were made on several lots, as described in a later section. Macroscopic, microscopic, thermal expansion, density and corrosion tests were also made on representative lots. As stated before, all lots were forged; and in addition, some were rolled hot and cold, some cold drawn, some upset cold, and such other operations carried out as to thoroughly test the workability of the materials.

DEFINITIONS

Five methods of determining and reporting "elastic limit" have been followed by investigators of corrosion-resistant steels, as follows:

1. True elastic limit
2. Proportional limit
3. Johnson limit
4. Proof stress
5. Yield point

The "true elastic limit" is taken as the greatest load which can be applied, that when the load is released, there shall be a re-

¹The figures in parentheses refer to the selected bibliography appended to this paper.

turn of the specimen to its original length, no permanent deformation having taken place.

The "proportional limit" refers to that load where the stress ceases to be proportional to the strain, that is, where the straight line ends in the ordinary stress-strain diagram.

The "Johnson limit" refers to the method proposed by the late J. B. Johnson, or Method No. 2 of Specification E8-24 of the American Society for Testing Materials, the elastic limit being taken as that stress at which the rate of deformation is 50 per cent greater than the initial rate of deformation.

"Proof stress" refers to that method in which the specimen is subjected to a stress, on removal of which the resultant deformation or permanent stretch shall not exceed 0.0002 inch.

By item 5, reference is made to a wide-spread practice of reporting "yield point" as "elastic limit." Such practice serves only to leave false impressions as to the real value of the material, and "yield point" should be reported as "yield point."

In this paper, both proportional limit and Johnson limit are reported for some materials, for purposes of comparison. In general, the Johnson limit is referred to, when the term "elastic limit" is used, as this appeared to better represent the matter and did not appear so subject to radical variance in its ratio to ultimate strength and other properties.

CHEMICAL ANALYSES

The chemical compositions of the selected lots are given in Table I.

Table I
Chemical Compositions of the Steels Tested

Serial	Maker	C	Mn	P	S	Si	Cr	Ni	Cu	W
6725	A—British	0.08	0.66	0.020	0.052	0.55	11.10	0.08	nil	....
M148	B—American	0.095	0.12	0.015	0.030	0.141	11.74	nil	0.096	....
M128	C—American	0.09	0.52	0.010	0.017	0.470	12.23	0.52	nil	....
M204	C—American	0.075	0.53	0.017	0.018	0.470	12.67	0.25	nil	....
M39	D—American	0.06	0.62	0.027	0.037	0.303	12.70	0.59	nil	....
M42	E—Swedish	0.08	0.84	0.014	0.020	0.376	12.78	0.37	0.130	....
M135	F—American	0.07	0.07	0.014	0.020	0.145	13.36	nil	nil	....
M36	C—American	0.075	0.51	0.021	0.014	0.022	13.87	nil	nil	....
6793	G—American	0.085	0.31	0.014	0.024	0.050	14.26	nil	nil	....
M27	H—American	0.05	0.51	0.024	0.010	0.680	17.42	nil	nil	0.14
M103	I—American	0.115	0.35	0.020	0.011	1.05	18.24	nil	0.060	....
M119	F—American	0.12	0.06	0.016	0.011	0.120	10.09	nil	0.83	....
M134	F—American	0.105	0.06	0.020	0.014	0.178	11.40	nil	0.30	....
M150	J—American	0.12	0.45	0.039	0.025	0.315	13.42	nil	1.06	....
6724	G—American	0.08	0.83	0.017	0.020	2.44	12.92	nil	nil	....

In general, the analyses were checked by two laboratories, one at South Philadelphia and one at East Pittsburgh. All were checked to a standard prepared from the entire cross-section and length of a one-inch round bar of this material, samples of this standard having been analyzed by the two Westinghouse laboratories, by a well known steel plant laboratory handling high chromium steels everyday, and by a second steel plant laboratory with a wide reputation as an authority in alloy steel analysis. The results were

	C	Mn	P	S	Si	Cr	Ni
Westinghouse	0.11	0.50	0.018	0.036	0.36	12.12	0.27
Westinghouse	0.075	0.53	0.018	0.038	0.394	12.05	0.44
Manufacturer	0.10	0.51	0.017	0.035	0.40	12.09	0.29
Manufacturer	0.11	0.507	0.025	0.041	0.401	11.90	0.20

HEAT TREATMENT

Thermal analyses were made on several materials, the results for steel No. 6725 being more or less representative:

Ac₁ 1346 degrees Fahr.
 Ac₃ 1563 degrees Fahr.
 Ar₃ 1508 degrees Fahr.
 Ar₁ 1292 degrees Fahr.

Steel No. 6724 showed an indication of an Ac₁ point at 1184 degrees Fahr., with no other arrest either heating or cooling.

To determine the best quenching temperature for heat treating these alloys, specimens of the Steel No. 6725 were quenched in oil from temperatures of 1600-1650-1700-1750-1800 degrees Fahr., and uniformly drawn to 1200 degrees Fahr., and when tested gave results as shown in Table II:

Table II
Physical Test Results

Serial	Quench	Elas. Limit	Yield Pt.	Ultimate	Elong.	Red.	Brinell	Izod
6725-1	1600° F.	60,000	75,500	97,750	27.0	70.3	207	66
2	1650° F.	62,000	81,500	102,000	29.0	69.3	235	66
3	1700° F.	69,000	91,500	106,000	21.0	65.2	235	63
4	1750° F.	75,500	91,000	102,000	22.5	67.0	235	62
5	1800° F.	71,500	90,000	105,500	21.0	68.2	235	59

Fig. 1 shows the uniformity in the appearance of the broken test specimens. The results indicated a fairly wide range of

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Cr	Ni
2.12	0.27
2.05	0.44
2.09	0.29
1.90	0.20

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at 1184 de-
oling.

r heat treat-
quenched in
egrees Fahr.,
when tested

	Brinell	Izod
	207	66
	235	66
	235	63
	235	62
	235	59

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quenching temperature, and 1750 degrees Fahr. was selected as the temperature giving the best results in general. It has been of interest to note that several manufacturers have also decided on 1750 degrees Fahr., for the quenching temperature. It has been

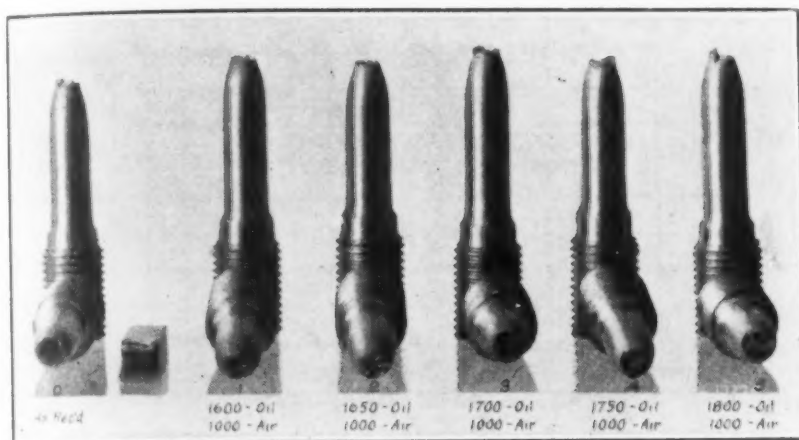


Fig. 1—Showing Uniformity in the Appearance of Broken Test Specimens of Material 6725 When Heat Treated as Shown.

suggested that 1825 degrees Fahr. or even higher would give better results, but the ultimate product in mind was of such nature as to prevent the use of higher temperatures than 1750 degrees Fahr., and results appear to confirm the selection of 1750 degrees as a good quenching temperature.

Except where otherwise noted, specimens were allowed to cool after forging, after which they were annealed. They were then uniformly heated in an electric furnace or salt bath to 1750 degrees Fahr. and quenched in oil, drawn back in a drawing bath or electric furnace, and cooled in the air.

TENSION-IMPACT-HARDNESS TESTS

Stainless iron is in general self-hardening when cooling from a forging or rolling heat, but not, of course, to the degree found in some of the higher carbon stainless steels. The results of tests on a few of the steels in the "as forged" condition are of interest and are given in Table III:

Table III							
Serial	Proportional Elas. Limit	Yield Pt. Lbs./Sq. In.	Ultimate Strength	Elong. %	Red. Area %	Brinell	Izod
6725	49,000	95,000	147,000	15.0	42.8	321	20
M39	90,000	105,000	175,500	12.0	52.0	340	35
M42	53,500	96,000	151,500	11.0	35.0	321	15
6793	25,500	32,500	96,500	19.0	48.6	207	23
M27	32,500	48,500	95,000	20.0	48.6	192	0

Fig. 2 shows the stress-strain curves for tension tests made on material M-42. The proportional limit, Johnson limit, and point of 0.010 inch extension, are shown on each. Curve 1 shows the results of test on the material as quenched but with no draw.

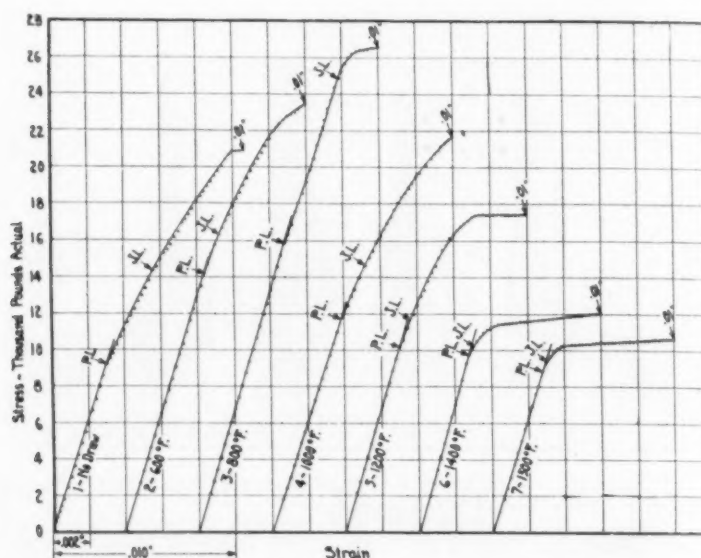


Fig. 2—Stress-Strain Curves for Tension Tests Made on Material M-42.

Curves 2 to 7 show the results with draws of 600-800-1000-1200-1400-1500 degrees Fahr. respectively. These curves are shown, not to give the values of proportional limit and Johnson limit, as they will be covered later, but to show the shape and nature of stress-strain curves for these materials. The irregularities between proportional limit and Johnson limit in curves 1-2-3 are of the order usually found in the more highly stressed conditions of heat treatment, that is, with rather low drawing temperatures. Curves such as 2-3-4 are often curved from the start and it is difficult to locate the proportional limit, yet by following the longer method of determining true elastic limit, a definite value can be determined. As the draw is raised above 800-1000 degrees Fahr., the curves partake of the more usual form, with the proportional limit and Johnson limit gradually coming together. These general conditions were observed by McAdam (2) on similar materials.

There is a method used considerably abroad in the testing of all metals and alloys, which is receiving much attention in this country as well, especially in the testing of non-ferrous materials, in which the yield point is determined as that load which produces

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clarities between
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longer method of
be determined.
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conditions were

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an extension of one-half of one per cent of the gage length, that is, an extension of 0.010 inch in a 2 inch standard gage length. The curves in Fig. 2 were carried to 0.010 inch extension, and the load recorded. The yield point was also determined in the usual way, that is, by the drop of the beam of the testing machine. A comparison of the results is made in Table IV:

Table IV			
Serial	Draw Deg. Fahr.	Yield Point Drop-of-beam	Yield Point 0.5% Extension
M42-1	0	none	104,750
2	600	114,000	117,500
3	800	131,000	132,500
4	1000	110,000	108,750
5	1200	87,000	87,000
6	1400	56,600	60,000
7	1500	50,500	53,000

Fig. 3 shows the results of tests on material 6725, quenched and drawn at 800-1000-1200-1400 degrees Fahr. There is a very

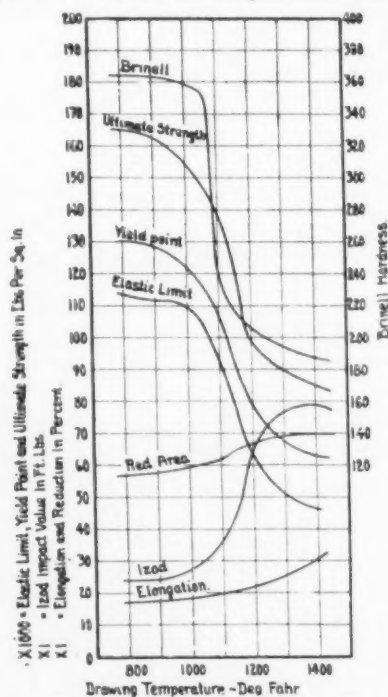


Fig. 3—Curves Showing the Results of Tests on Material 6725.

rapid falling off of strength between 1000 and 1200 degrees Fahr., and a corresponding increase in impact values, but without a corresponding rapid increase in elongation and reduction. The fractured test bars are shown in Fig. 4.

Fig. 5 shows the results of tests on material M-148, quenched

and drawn at 0-200-400-600-800-1000-1200-1400 degrees Fahr. The Johnson limit shows a maximum at 800 degrees Fahr. draw, and above that a fairly rapid falling off. Hardness, tensile strength and yield point may be considered fairly constant to 1000 degrees

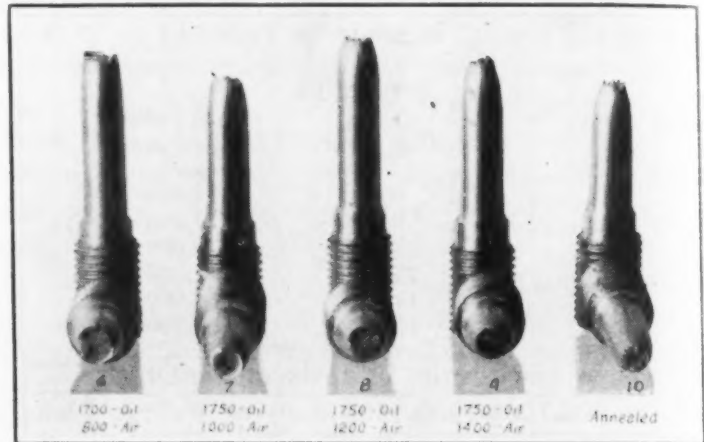


Fig. 4—Fractured Test Specimens of Material 6725 When Heat Treated as Shown.

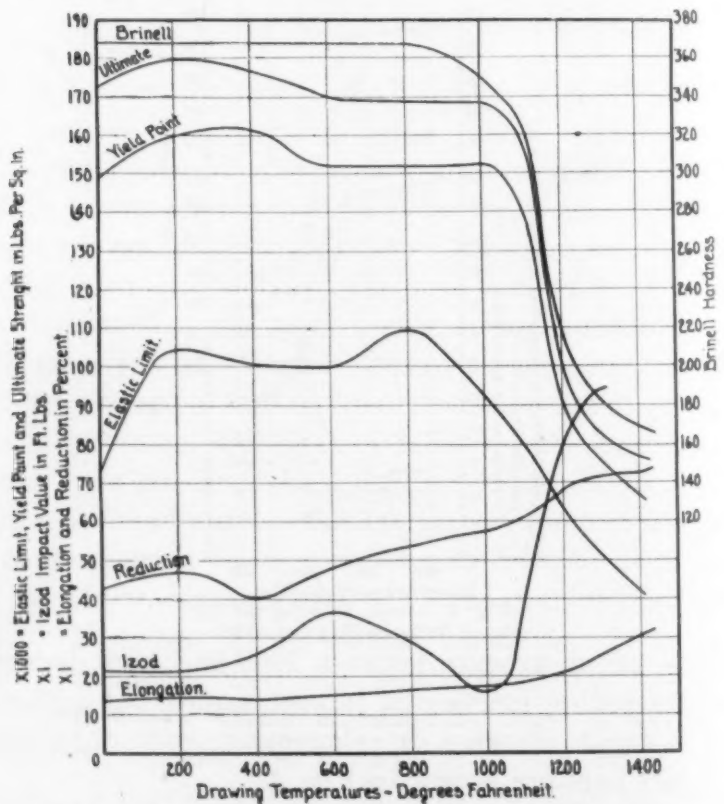


Fig. 5—Curves Showing the Results of Tests on Material M-148.

Fahr., with rapid decline from 1000 to 1200 degrees Fahr. A peculiar dip in the Izod curve from 600 to 1100 degrees Fahr. is shown, with the low point at 1000 degrees Fahr., and with exceedingly rapid rise at draws above 1000 degrees Fahr. The rise

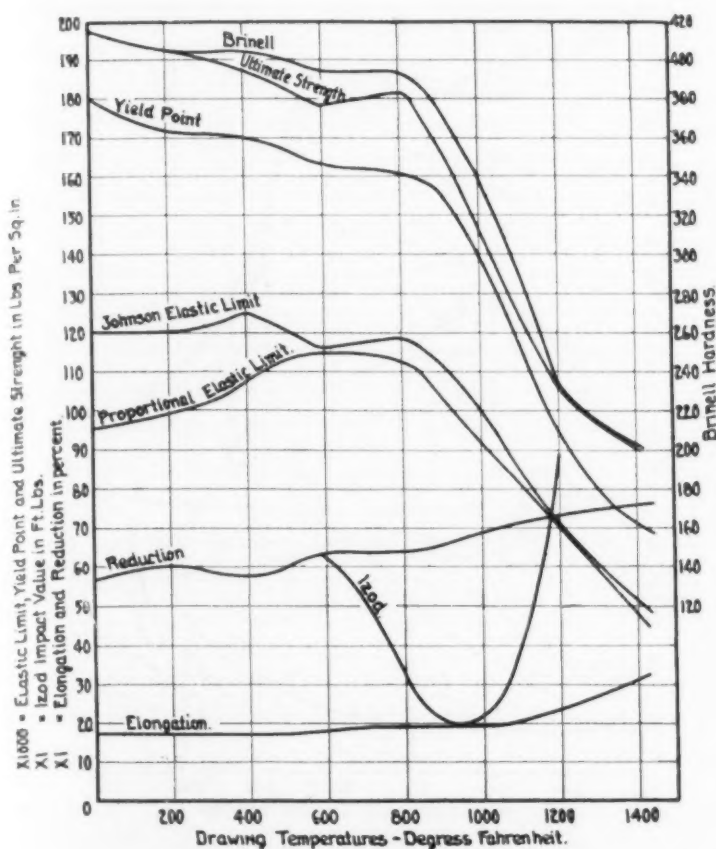


Fig. 6—Curves Showing the Results of Tests on Material M-128.

in elongation and reduction between 1000 and 1200 degrees Fahr. is not in proportion to the loss in hardness and strength.

Fig. 6 shows the results of tests on material M-128, quenched and drawn at 0-200-400-600-800-1000-1200-1400 degrees Fahr., and with Izod tests drawn at 600-700-800-900-1000-1100-1200 degrees Fahr. The dip in the Izod curve appears between 600 and 1100 degrees Fahr., with rapid rise with draws above 1000 degrees Fahr. Proportional limit and Johnson limit are shown, these coming more or less together at 600 degrees Fahr., but rapidly falling off when drawn above 800 degrees Fahr. There is but gradual loss of strength and hardness up to approximately 800 degrees Fahr., and rapidly falling away to 1200 degrees Fahr.

Again the increase in elongation and reduction does not appear proportional to the loss of strength and hardness.

Fig. 7 shows the results of tests on material M-204, quenched and drawn at 0-200-400-600-800-1000-1200-1400 degrees Fahr

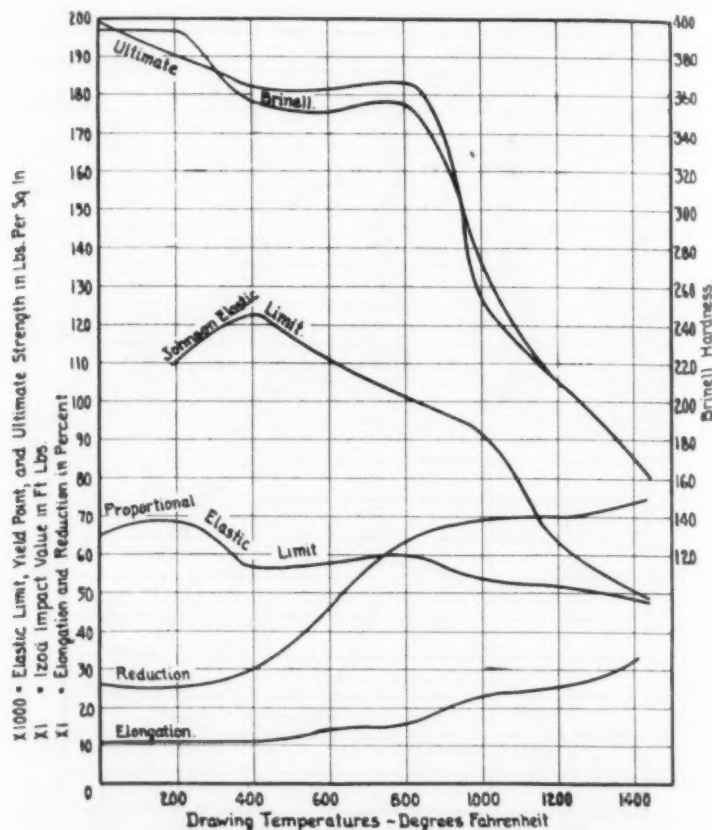


Fig. 7—Curves Showing the Results of Tests on Material M-204.

Maximum Johnson limit at 400 degrees Fahr., and the wide variation between proportional and Johnson limit are points of note.

Fig. 8 shows the results of tests on material M-39, quenched and drawn at 1000-1200-1400 degrees Fahr. The broken test bars are shown to the right of Fig. 9.

Fig. 10 shows the results of tests on material M-42, quenched and drawn at 0-600-800-1000-1200-1400 degrees Fahr. The stress strain diagrams shown in Fig. 1 were from these tests. A maximum of yield point and of Johnson limit are shown at 800 degrees Fahr., with fairly rapid fall of strength above 800 degrees Fahr.

Fig. 11 shows the results of tests on material M-135, quenched and drawn at 0-200-400-600-800-1000-1200-1400 degrees Fahr. A semblance of a dip in the Izod curve between 600 and 1050 degrees

Fahr. is shown. The maximum in Johnson limit appears at 800 degrees Fahr. In other respects the curves are more or less similar to those going before.

Fig. 12 shows the results of tests on material M-36, quenched

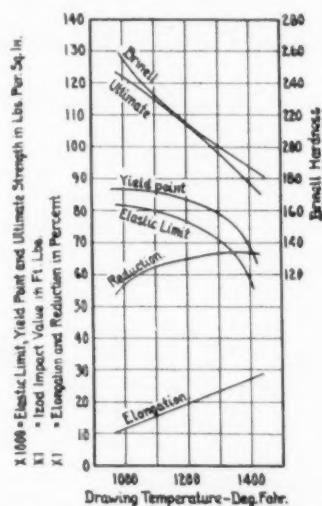


Fig. 8—Curves Showing the Results of Tests on Material M-39.

and drawn at 1000-1200-1400 degrees Fahr. The broken test bars are at the left of Fig. 9.

Fig. 13 shows the results of tests on material 6793, quenched and drawn at 0-200-400-600-800-1000-1200-1400 degrees Fahr. The Johnson limit curve shows a maximum at 800 degrees Fahr. There

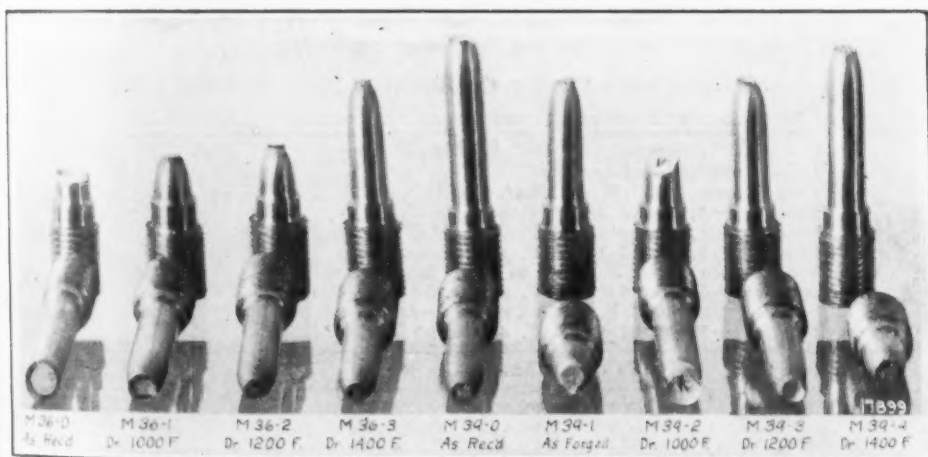


Fig. 9—Photograph of Broken Test Bars of Material M-36 and M-39.

is a fairly rapid fall in hardness, strength and yield point from the start. The broken test bars are shown in Fig. 14.

Table V shows the treatment and results of tests on material M-27. The forging and treatments would appear to be somewhat irregular, but are so designed to show the nature of the material. Low results in general for Johnson limit and ultimate strength are shown. The impact values are very low, except in 6 and 8, where the specimens were forged down to a black and subsequently

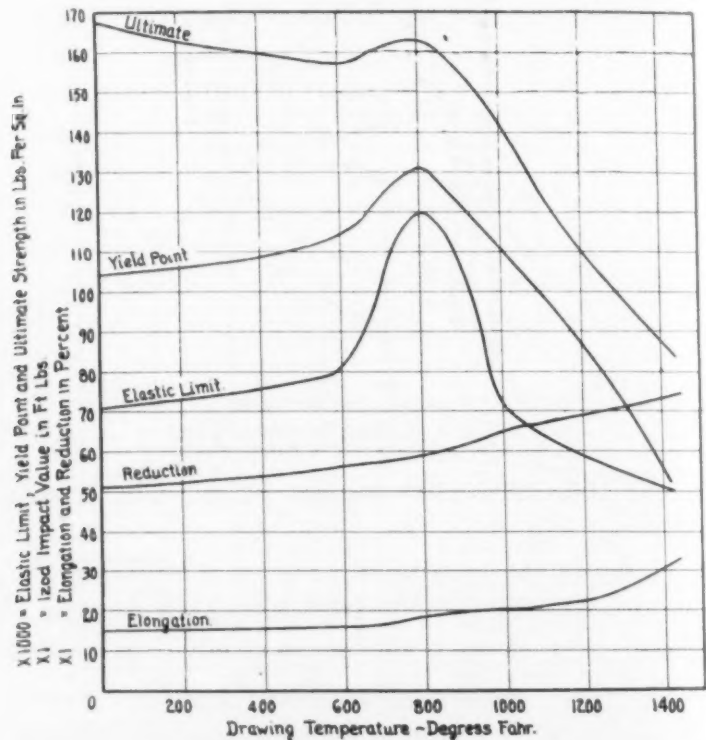


Fig. 10—Curves Showing the Results of Tests on Material M-42.

Table V

M27—0 As received—treated bar.

- 1 Forged from 1950° F. to 1650° F.—As forged.
- 2 Same as —1, heated 1500° F. and air cooled.
- 3 Same as —1, heated 1500° F. and water quenched.
- 4 Same as —1, heated 1750° F. and oil quenched.
- 5 Forged from 1950° F. down to black heat—As forged.
- 6 Same as —5, heated 1500° F. and water quenched.
- 7 Forged from 1400° F. down to black—As forged.
- 8 Same as —7, heated 1500° F. and water quenched.

Serial	Elas. Limit	Yield Pt.	Ultimate	Elong.	Red.	Brinell	Izod
0	31,500	38,000	68,000	38.5	76.0	146	27.54
1	32,500	48,500	95,000	20.0	48.6	192	0
2	43,000	50,000	76,000	30.0	69.9	159	2
3	32,500	47,500	73,500	29.0	68.4	156	8.35
4	27,000	41,500	84,200	6.0	10.8	190	0
5	40,000	67,500	101,000	19.0	44.0	228	7
6	31,500	53,000	76,500	27.0	72.0	166	115
7	59,000	67,000	81,500	24.0	70.3	187	9
8	34,500	42,500	70,000	36.0	78.5	166	87

quenched in water from 1500 degrees Fahr. Broken test bars are shown in Fig. 15.

Table VI gives the condition of treatment and results of tests on material M-103. The very splendid results shown by the cold drawn material are of interest.

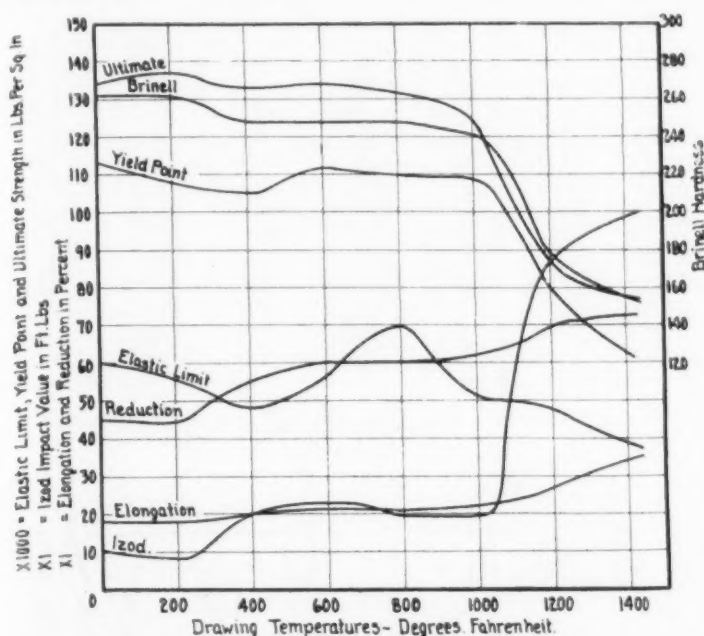


Fig. 11—Curves Showing the Results of Tests on Material M-135.

Fig. 16 shows the results of tests on material M-119, quenched and drawn at 0-200-400-600-800-1000-1200-1400 degrees Fahr. The dip in the Izod curve is from 600 to 1200 degrees Fahr., with rapid increase above 1100 degrees Fahr. Johnson limit and proportional

Table VI

M103—1 Hot-rolled.
—2 Cold drawn.
—3 Forged 1450° F. down to black.
—4 Forged 1950° F. down to 1300° F.
—5 Forged 1950° F. down to 1650° F.

Serial	Elas. Limit	Yield Pt.	Ultimate	Elong.	Red.	Brinell	Izod
1	52,500	67,500	90,000	28.0	58.8	202	0
2	79,000	88,500	102,500	22.0	66.6	223	71
3	64,000	75,500	92,000	26.0	66.3	212	28
4	43,000	none	116,500	13.5	19.2	223	0
5	48,000	70,000	112,500	6.0	10.4	228	0

limit show maxima at 900 degrees Fahr., as does also the yield point. Hardness and strength continue constant with slight rise at 1000 degrees Fahr., and rapid fall between 1000 and 1100 degrees Fahr.

Fig. 17 shows the results of tests on material M-134, quenched and drawn at 0-200-400-600-800-1000-1200-1400 degrees Fahr. The dip in the Izod curve is again between 600 and 1100 degrees Fahr.

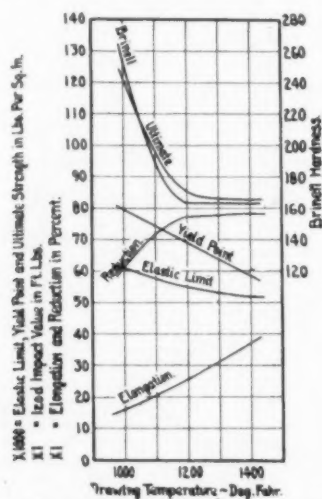


Fig. 12—Curves Showing the Results of Tests on Material M-36.

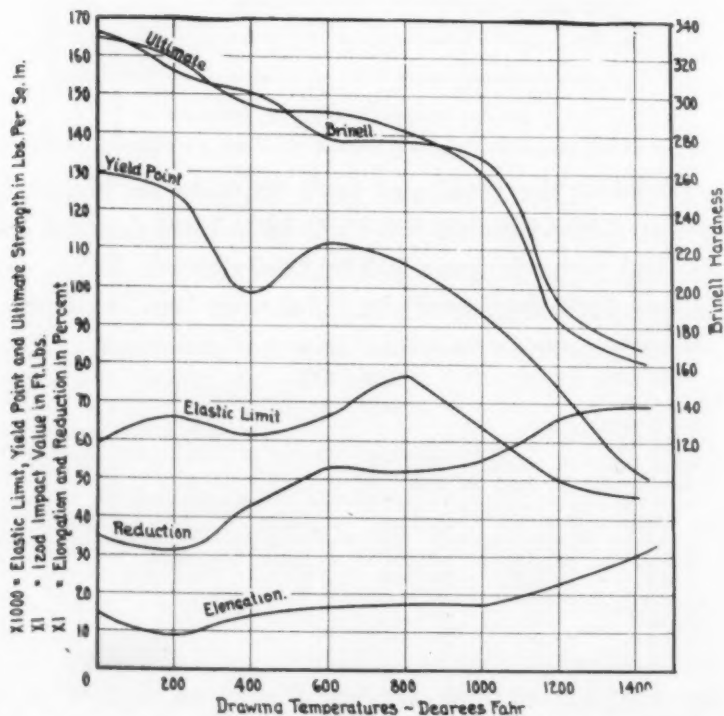


Fig. 13—Curves Showing the Results of Tests on Material 6793.

with rapid rise above 1050 degrees Fahr. The Johnson limit shows a maximum at 800 degrees Fahr. Strength and hardness continue

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constant up to 800 degrees Fahr., with very rapid fall between 1000 and 1200 degrees Fahr.

The results of tests on material M-150, quenched and drawn at 0-200-400-600-800-1000-1200-1400 degrees Fahr., are given in

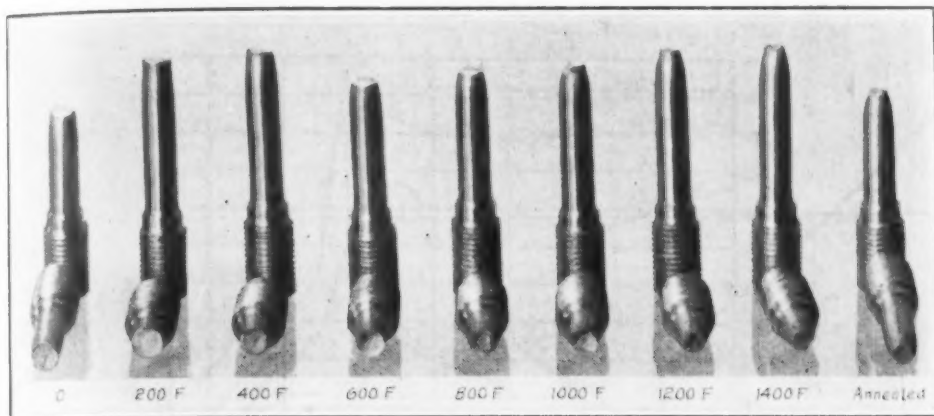


Fig. 14—Photograph of Broken Test Bars of Material 6793 After Quenching in Oil from 1750 Degrees Fahr. and Drawn as Shown.

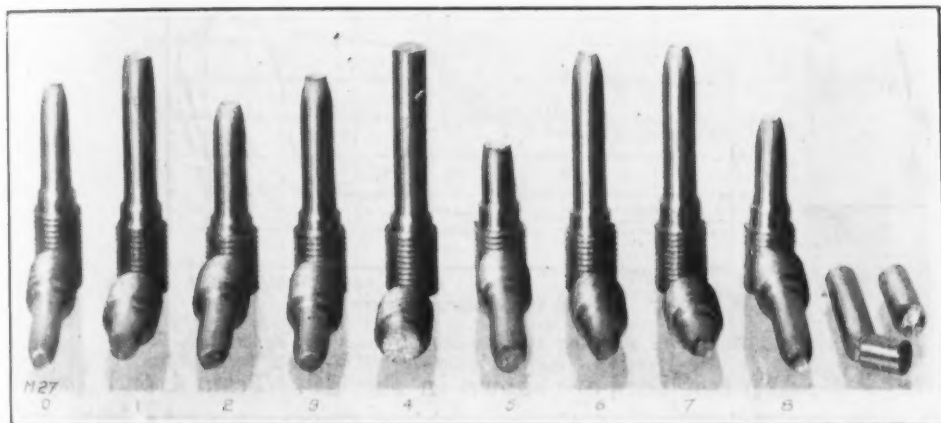


Fig. 15—Photograph of Broken Test Bars of Material M-27. See Table V.

Table VII

Serial	Elas. Limit	Yield Pt.	Ultimate	Elong.	Red.	Brinell	Izod
6724—1	Forged 1950° F. to 1650° F.—Treated 1750° F.—oil—1000° F.—air.						
—2	Forged 1950° F. to 1650° F.—Treated 1750° F.—oil—1200° F.—air.						
—3	Forged 1950° F. to 1650° F.—Treated 1400° F.—furnace.						
—4	Forged 1950° F. to 1650° F.—Treated 1800° F.—oil—1000° F.—air.						
—5	Forged 1950° F. to 1650° F.—Treated 1900° F.—oil—1000° F.—air.						
—6	Forged 1950° F. to 1650° F.—Treated 2000° F.—oil—1000° F.—air.						
1	50,000	60,000	90,000	18.0	19.5	207	0
2	48,000	62,500	90,000	10.0	11.2	207	0
3	46,000	65,000	92,000	13.0	14.7	212	0
4	59,000	67,000	92,250	29.0	57.3	212	0
5	58,000	68,500	91,500	27.0	43.4	212	0
6	55,000	67,000	88,000	8.5	7.4	207	0

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s continue

Fig. 18. The Izod curve shows a dip from 600 to 1200 degrees Fahr., with rapid increase above 1000 degrees Fahr. Maximum values for Johnson limit, yield point, strength and hardness occur at 800 degrees Fahr., with fairly rapid falling off at higher draws.

Table VII gives the treatment and results of tests on material

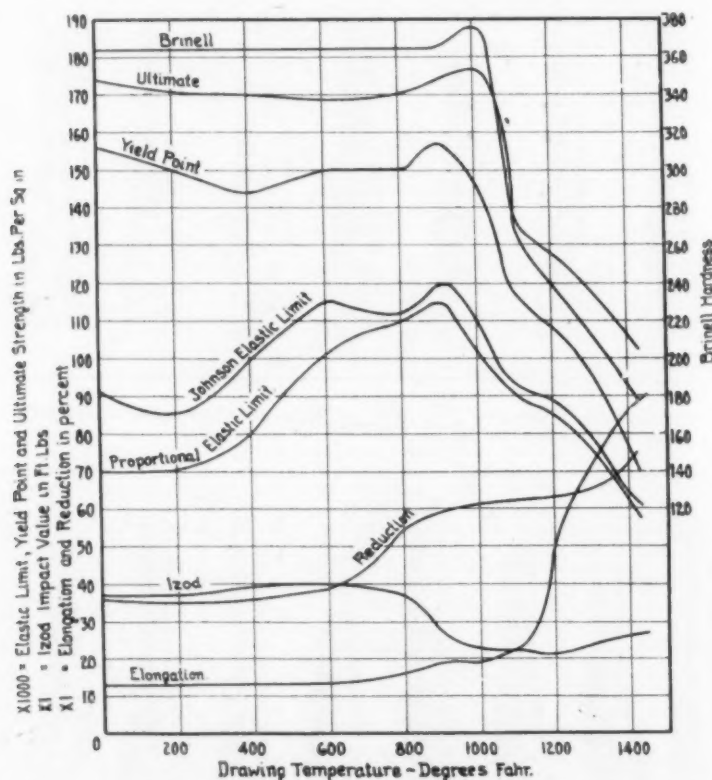


Fig. 16—Curves Showing the Results of Tests on Material M-119.

6724. Broken test bars are shown in Fig. 19. Tests 4 and 5 show the effects of increasing the quenching temperature to 1800 and 1900 degrees Fahr., by increasing the elongation and reduction. Zero impact values were found with all treatments.

PHOTOMICROGRAPHS

Photomicrographs at 100x, unless otherwise noted, are included, showing the structure found in some of the materials. These have been selected to cover in a general way, the range of chromium content. Table VIII, below, identifies the photomicrographs:

Figs. 28-29-30 at 100-35-15x respectively show the structure found in some drop forged specimens of material No. 6793. Fig. 30 shows practically the entire thickness of the forging.

Photomicrographs A of Figs. 28 and 29 show the central portion of the forging; and photomicrographs B show the outer portion of the forging. The exceedingly coarse structure continues across

Table VIII

Fig.	Material	Micrograph	Treatment	Remarks
20	6725	A	As received	
		B	1600—oil—1200—air	See Table II
		C	1650—oil—1200—air	See Table II
		D	1700—oil—1200—air	See Table II
		E	1750—oil—1200—air	See Table II
		F	1800—oil—1200—air	See Table II
21	6725	A	1750—oil—800—air	See Fig. 3
		B	1750—oil—1000—air	See Fig. 3
		C	1750—oil—1200—air	See Fig. 3
		D	1750—oil—1400—air	See Fig. 3
		E	Annealed 1500 deg. Fahr.	
22	M39	A	As received	
		B	As forged	See Table III
		C	1750—oil—1000—air	See Fig. 8
		D	1750—oil—1200—air	See Fig. 8
		E	1750—oil—1400—air	See Fig. 8
23	M36	A	1750—oil—1000—air	See Fig. 12
		B	1750—oil—1200—air	See Fig. 12
		C	1750—oil—1400—air	See Fig. 12
24	6793	A	As forged	See Table III
		B	Annealed 1500 deg. Fahr.	
		C	1750—oil—1000—air	See Fig. 13
25	M27	A	As received	See Table V
		B	As forged—1950-1650 deg. Fahr.	See Table V
		C	Same as B—1500 deg. Fahr.—air	See Table V
		D	Same as B—1500 deg. Fahr.—water	See Table V
		E	Same as B—1750 deg. Fahr.—oil	See Table V
26	M27	A	Forged 1950 deg. Fahr. to black	See Table V
		B	Same as A—1500 deg. Fahr.—water	See Table V
		C	Forged 1400 deg. Fahr. to black	See Table V
		D	Same as C—1500 deg. Fahr.—water	See Table V
27	M103	A	Hot-rolled	See Table VI
		B	Cold drawn	See Table VI
		C	Forged 1450 deg. Fahr. to black	See Table VI
		D	Forged 1950 to 1300 deg. Fahr.	See Table VI
		E	Forged 1950 to 1650 deg. Fahr.	See Table VI

the entire thickness, but toward the center are found other formations appearing at the grain boundaries and within the grains. We will refer to this condition at some length in a later part of the paper.

The etching agent used on the low chromium alloys was a solution of 19 grams ferric chloride and 6 cubic centimeters of hydrochloric acid in 100 cubic centimeters of water. For the higher chromium alloys, concentrated nitric acid with a few drops of hydrochloric acid added, was used.

FATIGUE TESTS

Table IX shows the results of endurance tests made on several materials. The tests on materials 6725 and 6793 were made at the Westinghouse Research Laboratory, using the rotating beam method. Those on material M-204 were made at the South Phila-

delphia Works Laboratory using the rotating cantilever beam method, and a second method using a fixed or non-rotating cantilever beam. Results of tests reported by McAdam (2) and Moore (3) are included for comparison:

Table IX

Material	Endurance Limit	Proportional Limit	Tensile Strength	Ratio—End. Limit to Tensile Strength
6725	92,000	80,000	156,000	0.58
6793	46,650	28,000	70,400	0.66
(Rotating) M204	62,000	57,000	121,000	0.51
(Fixed) M204	68,000	55,000	121,000	0.56
McAdam 0.08C-11.78 Cr.	74,000	24,500	166,500	0.45
McAdam 0.08C-11.78 Cr.	78,000	25,000	164,600	0.47
McAdam 0.08C-11.78 Cr.	61,000	none	109,500	0.56
McAdam 0.08C-11.78 Cr.	45,000	43,000	83,250	0.54
McAdam 0.08C-11.78 Cr.	31,000	20,000	63,250	0.49
Moore 0.03C-13.47 Cr.	40,000	18,000	82,400	0.42

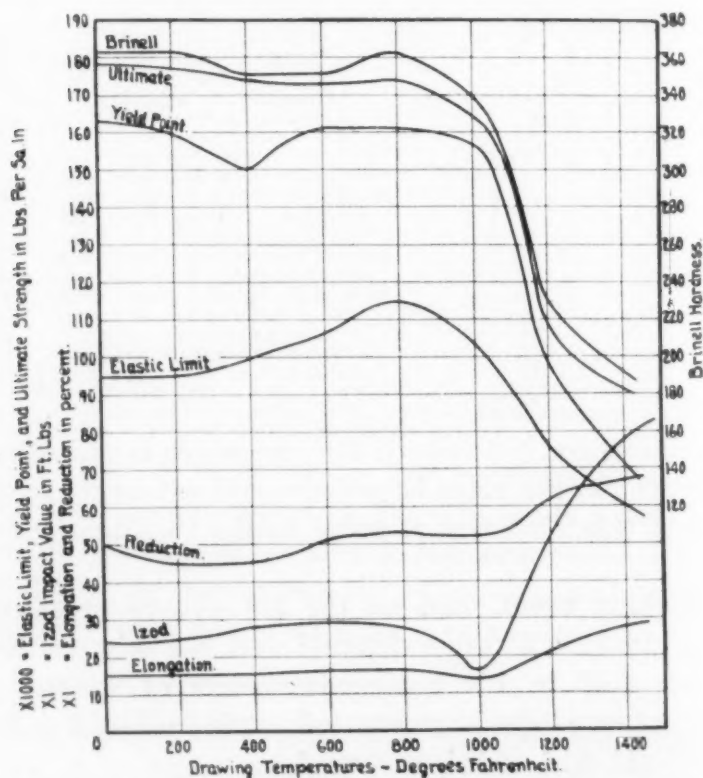


Fig. 17—Curves Showing the Results of Tests on Material M-134.

Other fatigue tests of a routine or acceptance nature have been made using the rotating cantilever beam method, in which materials of 11.5 to 13 per cent chromium content have been heat treated to show not less than 100,000 pounds tensile strength, and

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(2) and Moore

in which condition they were required to show not under 50,000 pounds endurance limit. No trouble has been experienced in meeting this condition.

EFFECT OF ELEVATED TEMPERATURES

The effect of elevated temperatures upon the physical properties and chemical stability of materials is an important consideration in the application of materials to various engineering and in-

atio—End. Limit
Tensile Strength

0.58
0.66
0.51
0.56
0.45
0.47
0.56
0.54
0.49
0.42

380
360
340
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M-134.

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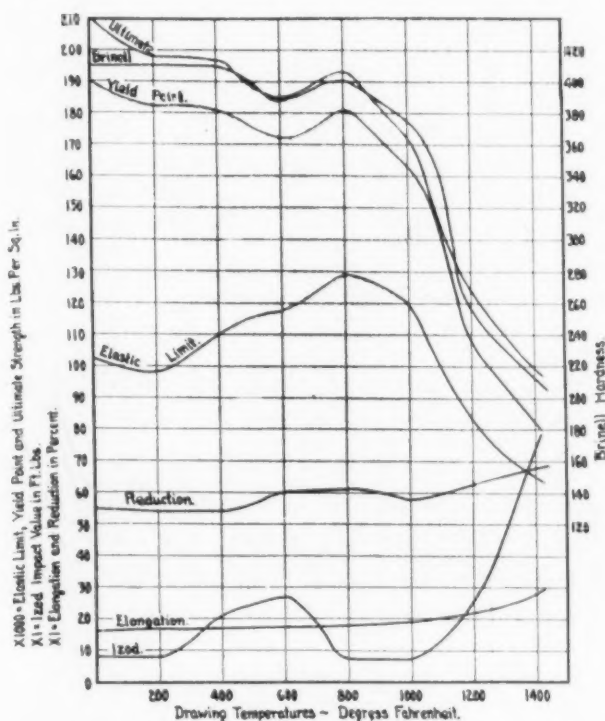


Fig. 18—Curves Showing the Results of Tests on Material M-150.

dustrial purposes. The Westinghouse Company has devoted considerable attention to this subject for several years, and among other materials, chromium-iron alloys have received and are receiving much attention.

Fig. 31 gives the results of "short-time" tensile tests on stainless iron, material M-128, in the quenched and drawn state. Tests were made at temperatures from 70 to 932 degrees Fahr. The results have been reported elsewhere (1) and require no further elaboration here.

An extensive program having to do with the effect of elevated temperatures on stainless iron and some other materials is now in

progress at the Westinghouse Research Laboratory, sponsored by the South Philadelphia Works. Both "short-time" and "long-time" tests of stainless iron in the annealed, and in the quenched and drawn states are being made. Results of "long-time" tests

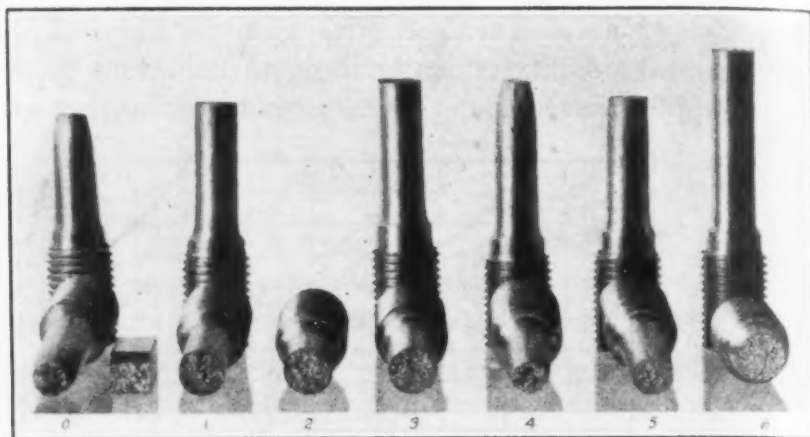


Fig. 19—Photographs of Broken Test Bars of Material 6724. See Table VII.

completed to date indicate that annealed stainless iron is susceptible to considerable strain hardening, and this is relieved but very slowly if at all at temperatures of 750 degrees Fahr.; further that specimens held under loads up to the proportional limit and at temperatures up to 750 degrees Fahr., show no additional deterioration with the time element. This work will be the subject of a joint report at a later date.

CORROSION

Tests to judge the resistance to corrosion have been made on practically all of the materials referred to. Cylinders, discs, and portions of forgings have been subjected to the action of steam, heat, running tap water, salt water, salt spray, stagnant water, atmosphere and the elements, dilute and concentrated acids, magnesium chloride, calcium chloride and some other conditions. Such tests in the absence of definite standards, can only serve to indicate the general behavior, and for the present purpose, general results or conclusions will be given rather than many meaningless figures. The general indications are:

1. That heat treatment which is so essential to bring out the resistance to corrosion in the higher carbon stainless steel, appears entirely unnecessary with stainless iron.

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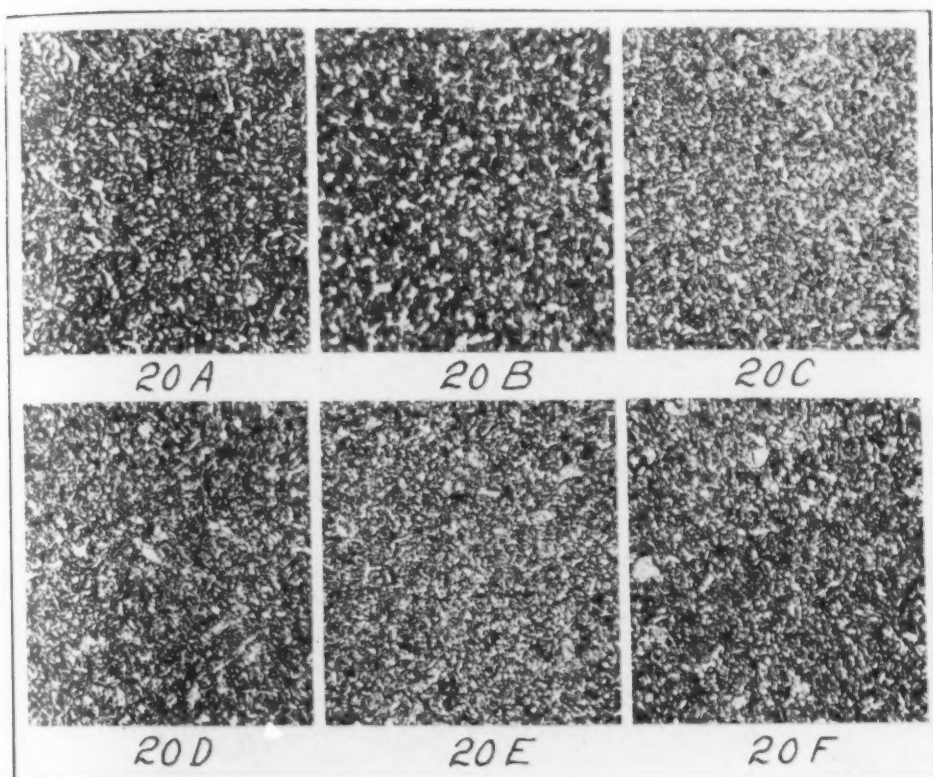
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2. Increase in chromium content, and especially those alloys of high chromium content containing silicon, appear to offer more marked resistance than the low chromium alloys.



Figs. 20A-20F—Photomicrographs of Material 6725 Heat Treated as Shown in Table VIII. Physical Test Results Shown in Table II. Mag. 100x.

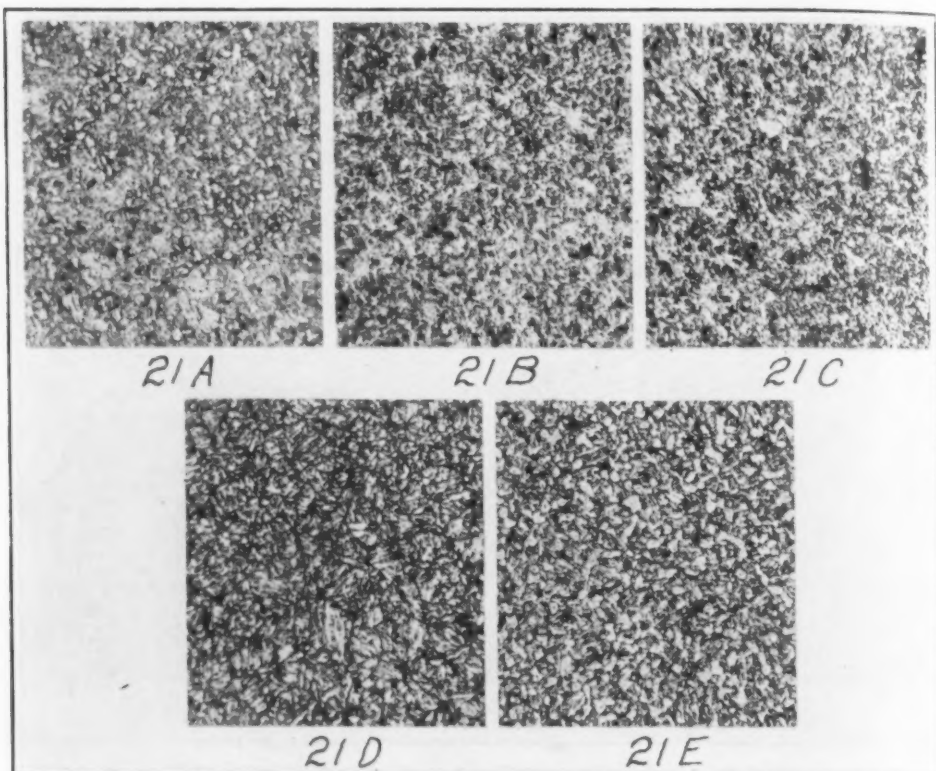
3. That increased silicon gives greater resistance to scaling.

4. That the addition of 1 per cent copper appears to increase the resistance to salt water or spray.

5. That a properly prepared pickled surface is quite resistant to actual corrosion, although it may show some superficial rust. A case in mind is that of a forging with improperly prepared pickled surface being left on an outdoor scrap pile for several weeks. A coating of rust appeared all over. Leaving one third of the surface in this rusted state, a second third was properly pickled, and the other third polished. After being outdoors subject to

the elements for nearly two years, the rusting of the original third has progressed no further and the other portions are without change.

In general, the results of the tests would cause us to confirm many of the conclusions and data given by Parmiter (4), Arm-



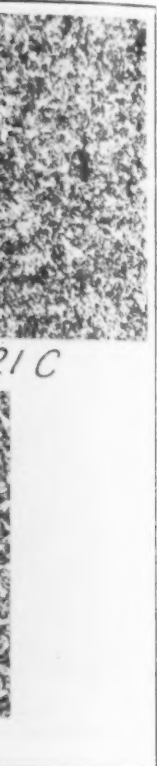
Figs. 21A-21E—Photomicrographs of Material 2725 Heat Treated as Shown in Table VIII. Physical Test Results Shown in Fig. 3. Mag. 100x.

strong (5), Primrose (6), Strauss (7), and others, who have dealt more in detail with this phase of the matter.

Of especial interest to many, is the resistance of these materials to the corrosive and erosive action of wet and dry steam under varying temperatures up to 750 degrees Fahr., with and without foreign or other matter which would accelerate either action. Fig. 32 shows a small machine for the purpose of making a study of this matter which study is now in progress. It consists of a steam tight casing in which a shaft is revolved by means of a pulley, driven by a motor not shown. The shaft at its opposite end carries as disk and deflector, with ten specimens secured to the disk as shown. Steam or water entering by means of the nozzle is de-

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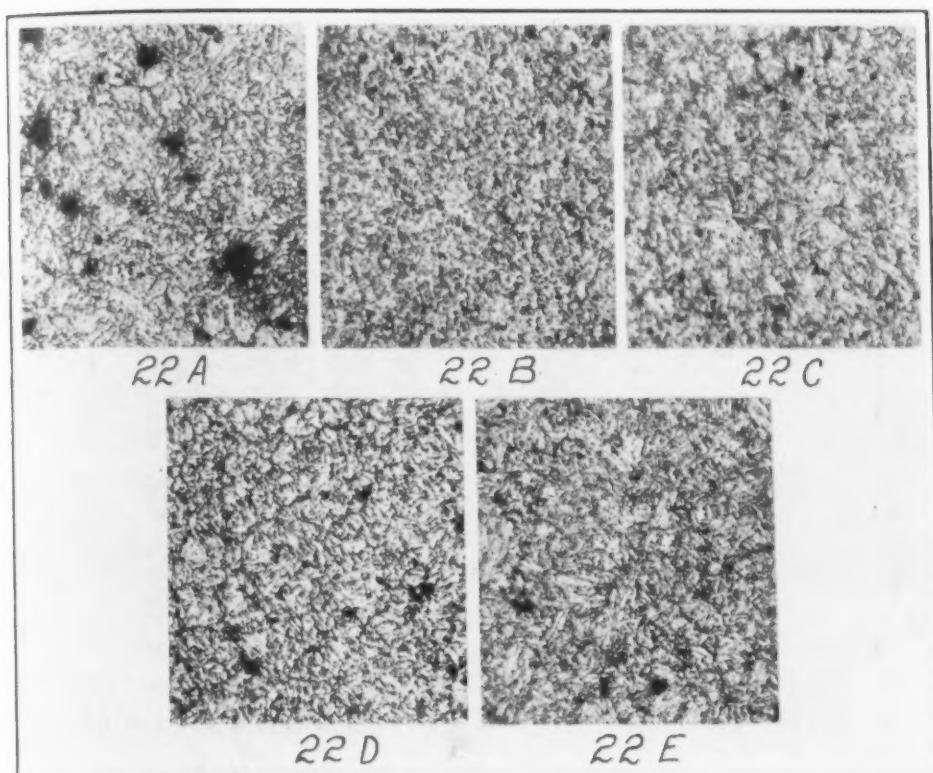


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flected against the sharp edges of the specimens. A second nozzle, not shown, permits of the steam or water impinging directly on the specimens without the use of the deflector. Both nozzles are pro-

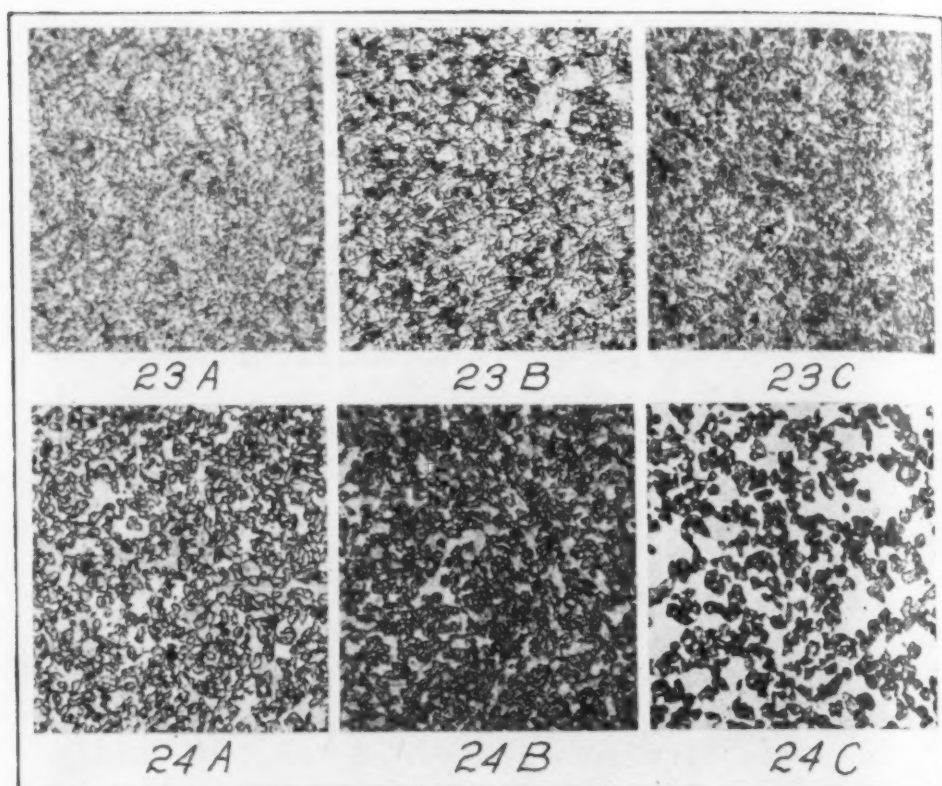


Figs. 22A-22E—Photomicrographs of Material M-39 Heat Treated as Shown in Table VIII. Physical Test Results Shown in Fig. 8. Mag. 100x.

vided with an injector arrangement permitting the introduction of any chemical or gas into the steam or water. The purpose of revolving the specimens is to secure uniform subjection of all specimens to the corroding or eroding medium, something which is often unaccomplished in many corrosion tests. Stainless iron is being examined extensively in this way, and the results will be available at a later date.

MISCELLANEOUS CHARACTERISTICS

One of the most objectionable features of nonferrous metals and alloys in general and of many corrosion resisting ferrous materials as well, is the rather high rate of thermal expansion. This feature is often a difficult one to contend with, when the design includes main parts of ordinary iron and steel. Determinations



Figs. 23A-23C—Photomicrographs of Material M-36 Heat Treated as Shown in Table VIII. Physical Test Results Shown in Fig. 12. Mag. 100x.

Figs. 24A-24C—Photomicrographs of Material 6793 Heat Treated as Shown in Table VIII. Physical Test Results Shown in Fig. 13.

of the coefficient of expansion of stainless iron have been made, and compared with other corrosion resisting materials:

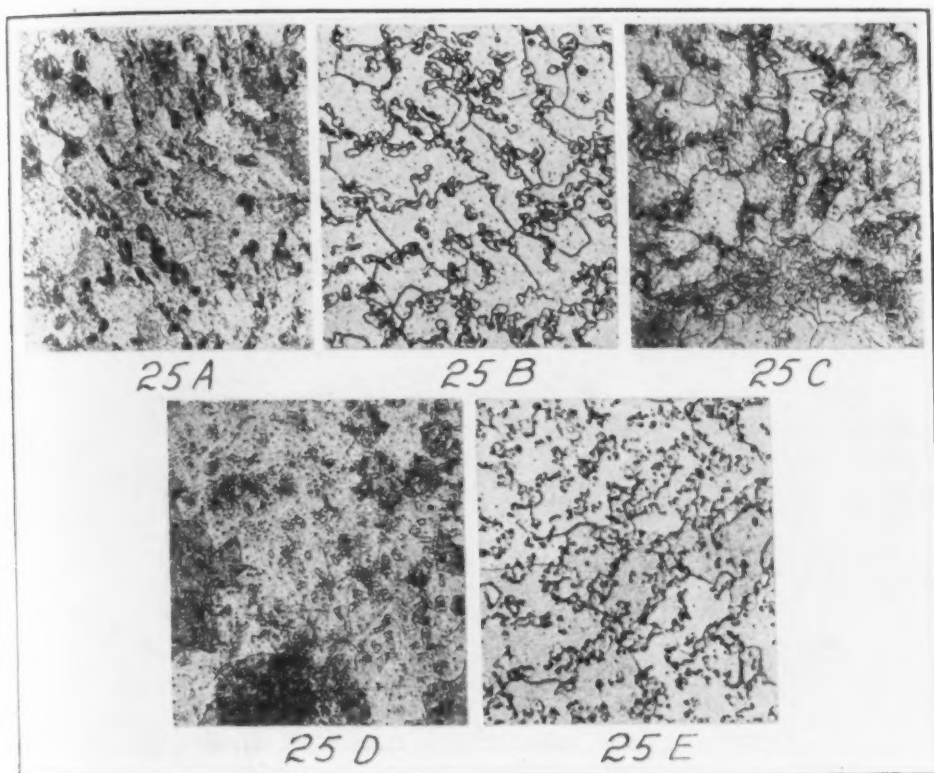
Material	Mean Coefficient of Thermal Expansion. 0-500 Deg. Cent.		
6725 Stainless Iron	12.00	$\times 10^{-6}$	per degree Centigrade
M-27 Stainless Iron	11.64	$\times 10^{-6}$	per degree Centigrade
20% Nickel—7% Chromium Steel	19.20	$\times 10^{-6}$	per degree Centigrade
99% Nickel	15.03	$\times 10^{-6}$	per degree Centigrade
Aluminum Bronze	21.20	$\times 10^{-6}$	per degree Centigrade

It is indeed gratifying to find a corrosion resisting material with a rate of expansion comparable with ordinary iron and steel.

Another point of interest, and in some matters of design of extreme value, is that stainless iron is lighter in weight than ordinary steel, due to the alloying agent, chromium, being lighter than iron. Invariably, corrosion resisting materials are considerably heavier than ordinary steel. Determinations of weight averaged 0.275 to 0.278 pounds per cubic inch.

The writer has chosen to apply the term "affinity" to that

characteristic of many metals and alloys to gall or stick when operating in contact with the same or like materials. The condition as a rule is aggravated by elevated temperatures. Stainless iron is known to exhibit this shortcoming in many instances, cases being

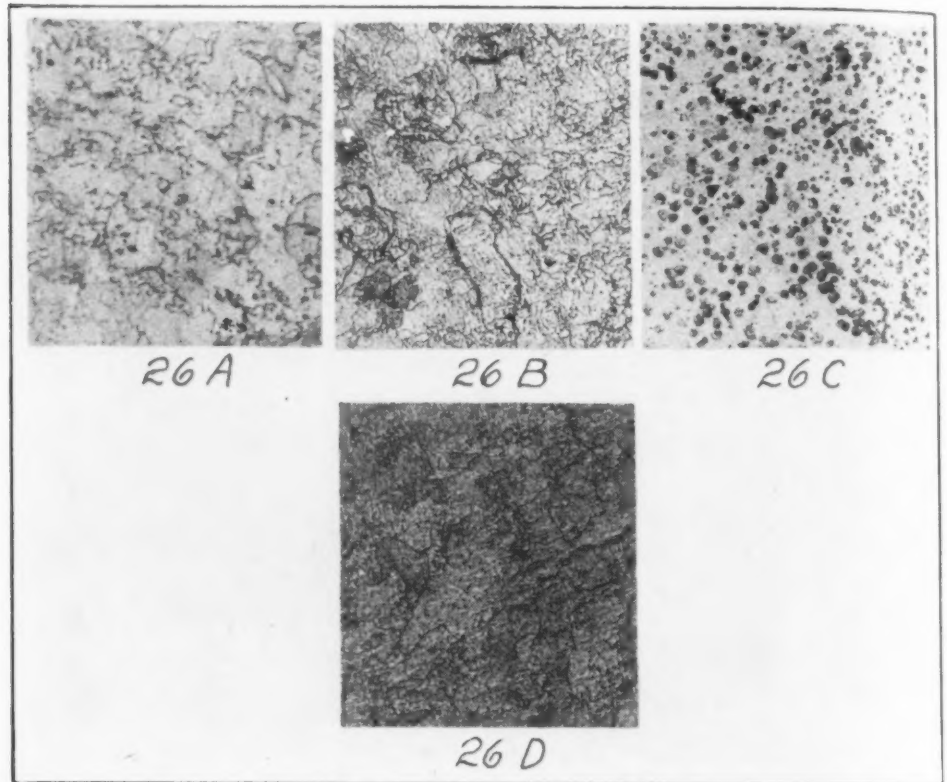


Figs. 25A-25E—Photomicrographs of Material M-27 Heat Treated as Shown in Table VIII. Physical Test Results Shown in Table V. Mag. 100x.

experienced in which slide valves of a given design operated entirely satisfactorily in three installations, only to gall badly in two other installations. Various methods of overcoming the trouble have been suggested and are being practiced today, of heat treating the parts to show different states of hardness, or of varying the chemical composition of the two parts by the addition of carbon, chromium or nickel to the one. This matter of "affinity" is being made the subject of a special investigation at the South Philadelphia Works, and stainless iron is receiving first attention.

The etching of cross-sections of rolled bars, for macroscopic examination, has revealed some interesting conditions. Figs. 33 to 38 inclusive show the results of such tests, these being selected as best representing the structures found. Fig. 33 and the lower

specimen of Fig. 36 represent materials No. 6725 and M-119 respectively and exhibit sound material. The dark center in Fig. 34 is of the nature of pipe, and would no doubt open up during forg-

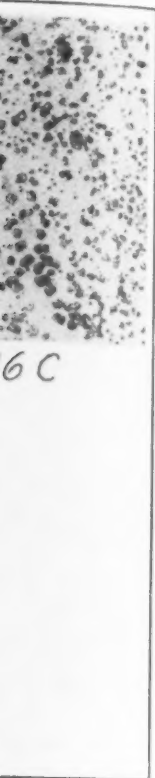


Figs. 26A-26D—Photomicrographs of Material M-27 Heat Treated as Shown in Table VIII. Physical Test Results Shown in Table V. Mag. 100x.

ing. The radiating streaks, resembling cracks, shown in Figs. 35-36 (upper) 37-38 have often been found and are considered as cause for rejection. They usually result in hammer piping or splitting during forging. The accompanying segregation in Figs. 35-38 has been observed at numerous times.

Figs. 35 and 38 best serve to illustrate another condition worthy of mention. In the cross-section at the right of Fig. 35 and in specimen Fig. 38, will be observed numerous small rounded and irregular black spots, mostly towards the outside of the section. In the longitudinal section these appear as streaks. The defects are needle-like in form, drawn out in the direction of the rolling, and are non-metallic in nature. They are troublesome in many ways, appearing on the outside of the bars and extending

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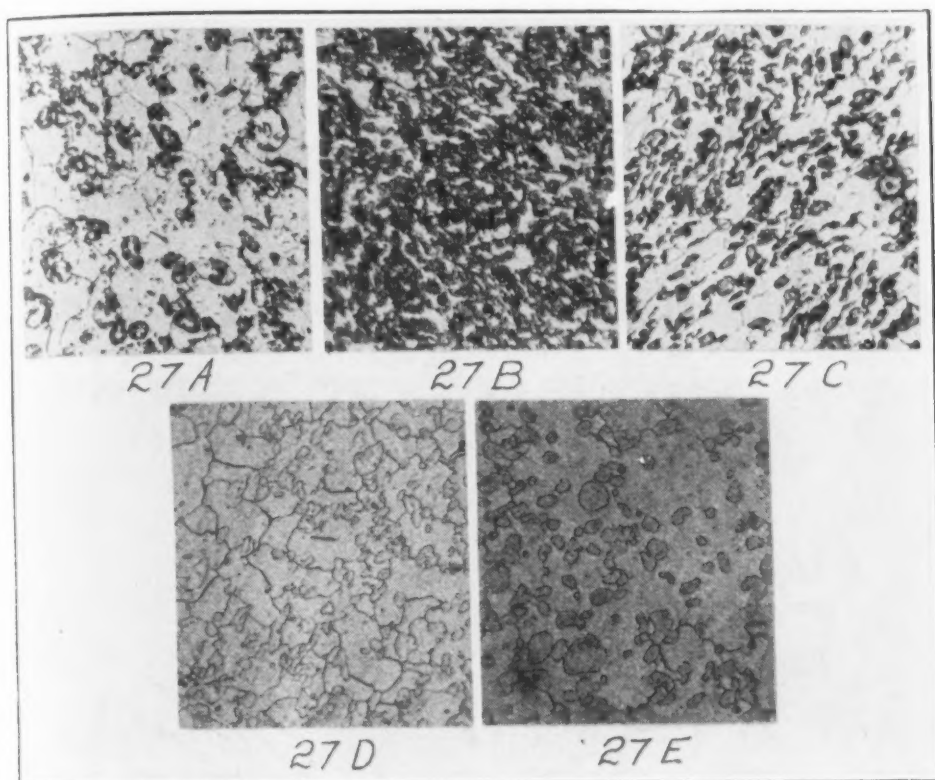


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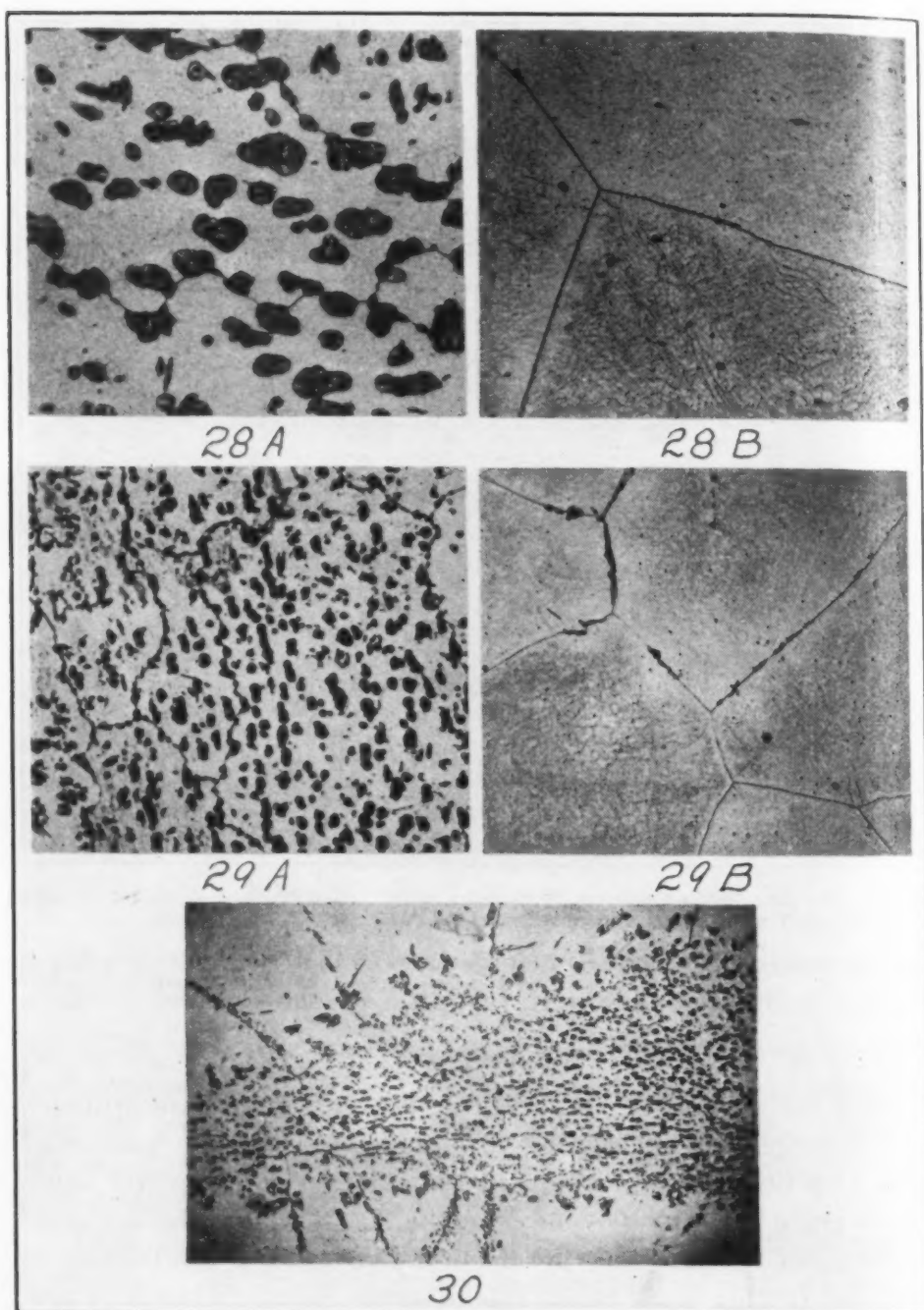


Figs. 27A-27E—Photomicrographs of Material M-103. Heat Treated as Shown in Table VIII. Physical Test Results as Shown in Table VI. Mag. 100x.

cerned, but in producing a forged or rolled product requiring pickling operations they will reappear in the finished product.

FORMING

The hot working of stainless iron requires more than ordinary care. Overheating, or heating to high temperatures a number of times with little or no subsequent reduction or working will cause serious grain growth. On the other hand, the air hardening characteristics of the alloys of lower chromium make it inadvisable to carry out further work below 1650 degrees Fahr. When it is possible to continue the forging through the full range, a working range of 2100-1650 degrees Fahr. has been found satisfactory for the lower chromium alloys. However, if only little reduction is to be made in the forging, it is recommended that the forging range be 1950-1650 degrees Fahr.



Figs. 28A and 28B—Photomicrographs of Material of Drop Forged Specimens of Material 6793. Mag. 100x.

Figs. 29A and 29B—Photomicrographs of Material of Drop Forged Specimens of Material 6793. Same as Figs. 28A and 28B. Mag. 35x.

Fig. 30—Photomicrograph Same as 28A and 29A. Mag. 15x.

The higher chromium alloys may be safely worked down to a black heat. It is not recommended that they be heated higher than 1950 degrees Fahr. and even then grain growth will take place if forging is discontinued at a high heat. These alloys have been successfully forged from 1400 degrees Fahr. to a black.

In hot rolling, stainless iron in general tends to spread more than ordinary steels, and over-fill the rolls, forming fins, which

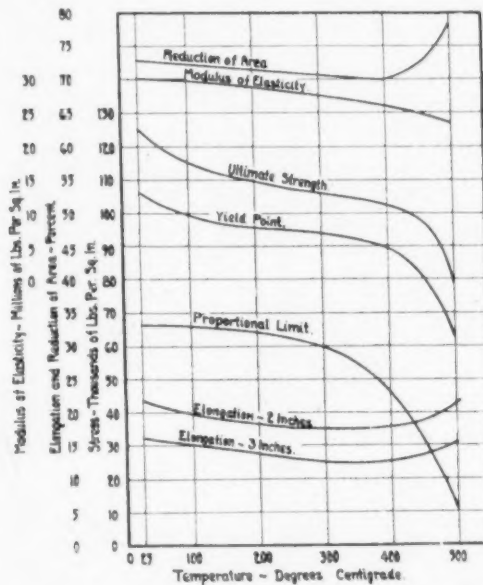


Fig. 31—Curves Showing Short Time Tensile Test Results on Stainless Iron Material M-128 in the Quenched and Drawn State.

on the next passes result in laps or folds. Scale is usually folded or rolled in at the same time. This condition has been a source of constant trouble, and has in many cases compelled the use of turned or ground rods for forged or rolled product.

The alloys in general may be cold-rolled, drawn, upset, pressed, or otherwise cold worked. Experience has shown that the amount of work between anneals and the speed of working are greatly reduced over soft carbon steel, and the wear on rolls, dies or other tools greatly increased. Where expedient, cold rolling is practiced in preference to cold drawing. For annealing, dead softness will result by heating to 1800 degrees Fahr., and cooling very slowly; but for most cold working operations annealing at 1400-1450 degrees Fahr., and cooling in the furnace or air will be sufficient.

The formation of scale and its removal is a matter requiring

considerable care, in the heating of stainless iron for the various purposes, especially when annealing for subsequent cold forming operations. The scale is usually removed readily after hot rolling or forging, by a number of pickling solutions. If, however, the

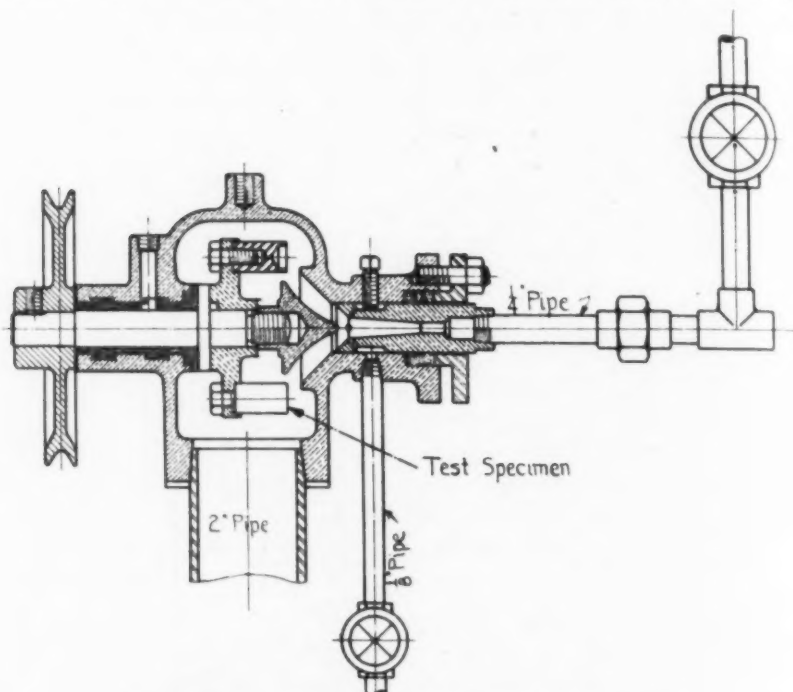


Fig. 32—Sketch of Corrosion and Erosion Test Apparatus.

steel is annealed without first removing the scale, under certain furnace conditions the scale will become baked on in such manner as to make its removal a difficult and serious matter. For cold working, it would appear the better plan to use scale-free stock to start, preferably turned or ground stock, and prevent so far as possible any serious scaling by carrying out annealing in closed tubes or pots, or better still in a suitable salt bath.

DISCUSSION

Of especial interest is the depression or dip in the Izod curve beginning at approximately the 600-degree Fahr. draw and with full recovery when drawn at 1100 to 1200 degrees Fahr. The condition is shown in seven of the curves submitted, or in all cases where Izod impact tests were made over this range. Monypenny (8) devoted some attention to the Izod values of a similar material, but shows a straight horizontal line from approximately 700 to 975

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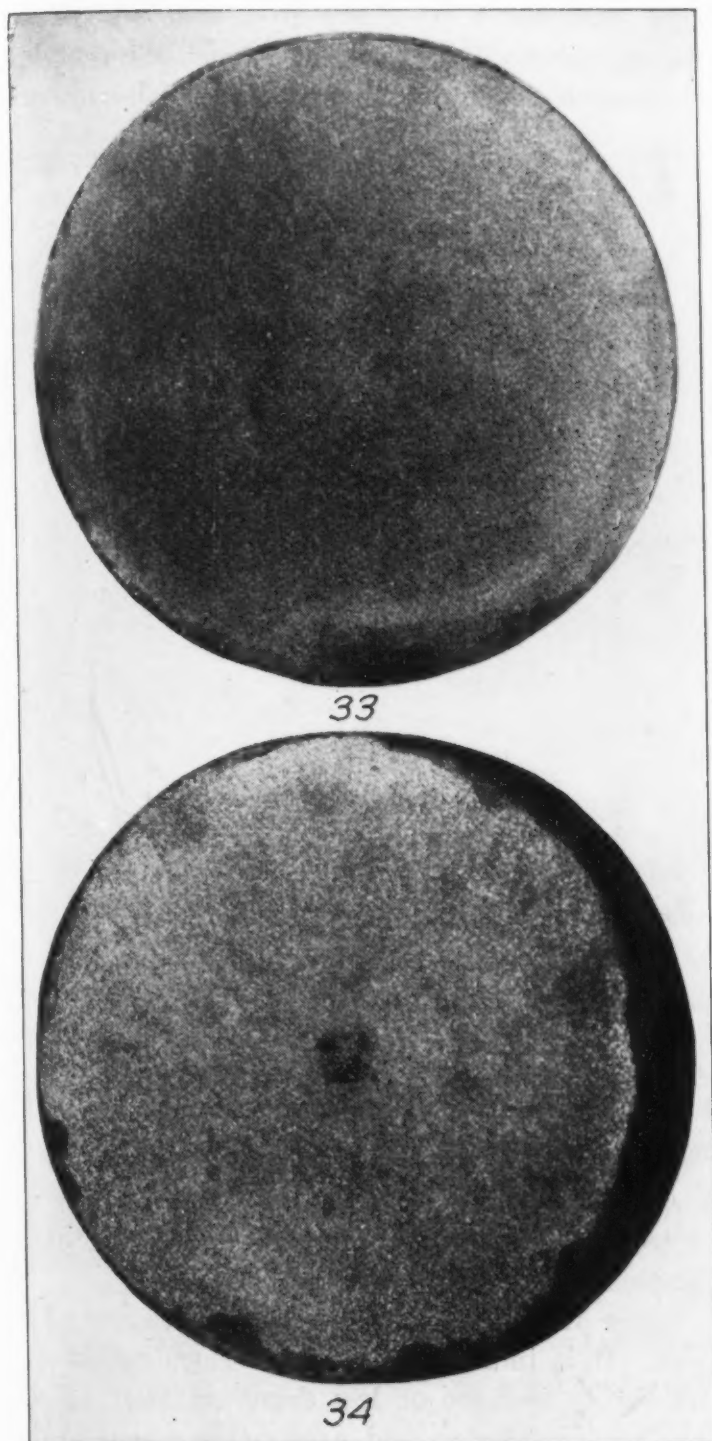


Fig. 33—Deeply Etched Specimen of Material 6725. Mag. 3x.
Fig. 34—Deeply Etched Specimen Showing a Dark Center
Which is of the Nature of a Pipe.

grees Fahr. Observed especially in alloys under 14 per cent chromium, it is suggested that some structural rearrangement is taking place, such as the decomposition of retained austenite from

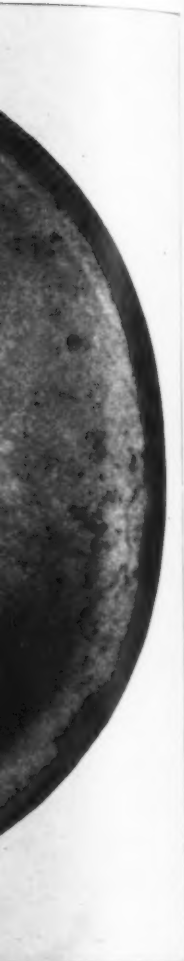


Fig. 35—Deeply Etched Specimen Showing Needle-Like Nonmetallic Defects. Mag. 125x.

the oil quench. This shape of the Izod curve becomes of practical import in treating materials to meet current specifications requiring Izod impact tests.

The matter of elastic limit was discussed at some length in an earlier part. It is indicated that the determination of the limit of proportionality is more or less dependent on the accuracy or fineness of the extensometer used, even to the extent of determining no such limit, by reason of finding a stress-strain line curved from its start. Yet a true elastic limit may exist with such a curved

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line. This matter appears to warrant further investigation.

The endurance limit of stainless irons would appear more or less comparable with other steels in the ratio to tensile strength.

In two cases, a Brinell hardness of over 400 was observed, which indicates the ability of iron-chromium alloys to harden with proper treatment, without the aid of other alloying elements. Monypenny (8) and Armstrong (9) have commented on this matter.

It would appear from results given in Table IV that the method of determining yield point as the load resulting in an extension of one-half of one per cent of the gage length can be used to advantage in testing stainless irons.

In general, the curves show the customary effect of increasing draw temperatures, by a falling off of the strength and hardness, and by increasing ductility. In many cases, however, very abrupt changes in tensile strength and hardness occurred without a corresponding abrupt change in ductility. A fall of tensile strength from 155,000 pounds to 98,000 pounds per square inch occurred in one place by increasing the draw from 1000 to 1200 degrees Fahr., with the change in elongation from 18 to 22 per cent and in reduction of area from 59 to 67 per cent. In another, the fall in strength was from 169,000 pounds to 100,000 pounds per square inch, with elongation and reduction increasing from 17 to 21 per cent and 58 to 68 per cent respectively. The curves of strength and hardness in these cases are so nearly perpendicular as to render impractical any attempt to retain the physical properties in that portion of the curve, with any degree of uniformity.

Relative to the effect of composition on the physical properties and other characteristics, the fact that the materials were produced by many manufacturers under different conditions and from various sized ingots, would indicate that irregularities would occur which would not be present in a pure laboratory investigation with materials under uniform control. Despite this condition, the results show decided indications of the effect of varying composition.

Carbon bears a most important part in alloys of this type, but as it was carefully maintained under 0.12 per cent, it will not be considered here.

Chromium is of course the matter of greatest importance. A general comparison of the results of tests reveals the fact that up

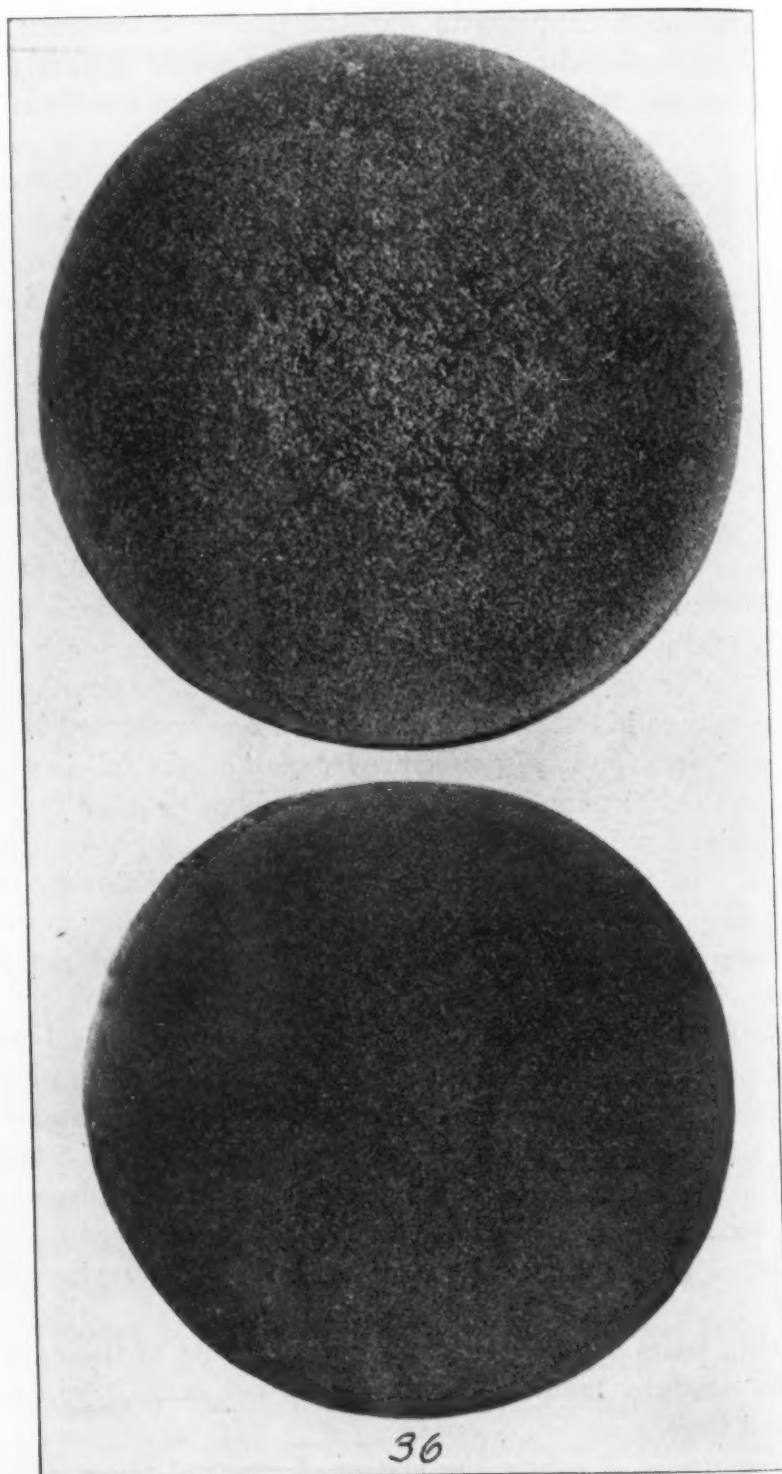


Fig. 36—Deeply Etched Specimens (Upper) of Material 6725 and (Lower) Material M-119. Mag. 1.25x.

to approximately 13 per cent chromium, the alloys behave much the same in heat treating. Above 13 per cent however, there is a marked falling off of physical properties, this being more marked

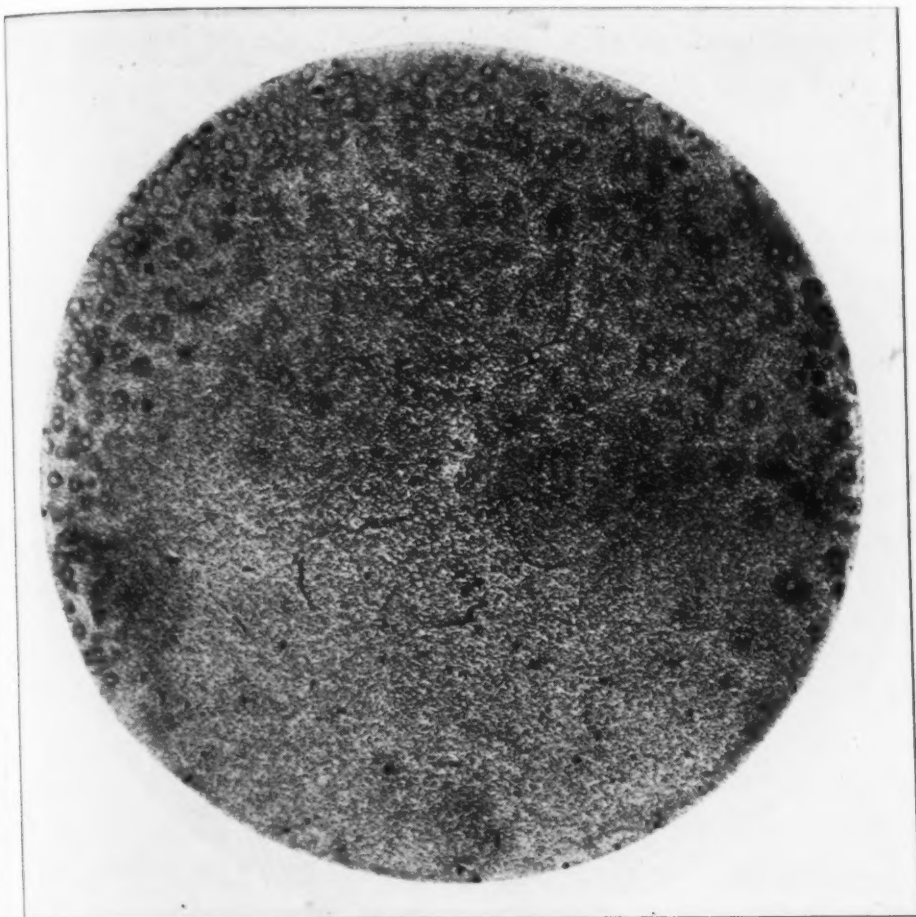


Fig. 37—Deeply Etched Specimens Showing Internal Defects Which Usually Result in Hammer Piping or Splitting During Forging. Mag. 1.50x.

as to elastic limit than tensile strength and hardness. It was early found that falling off in physical properties occurred somewhere between 13 and 14 per cent chromium, and that increased chromium finally resulted in an entire loss of ability to harden or improve the physical properties by quenching. In forging the various materials, a similar general division of characteristics was found between 13 and 14 per cent chromium. Those under 13 per cent chromium hardened on air cooling and could not be worked under 1650 degrees Fahr. Those over 14 per cent in chromium appeared much softer, they did not harden to the same extent on cooling, but they

showed a tendency toward grain growth of a serious nature. Such grain growth is shown by Figs. 28-29-30. The coarse grains became evident on pickling the forgings, and often existed to $\frac{5}{16}$ inch

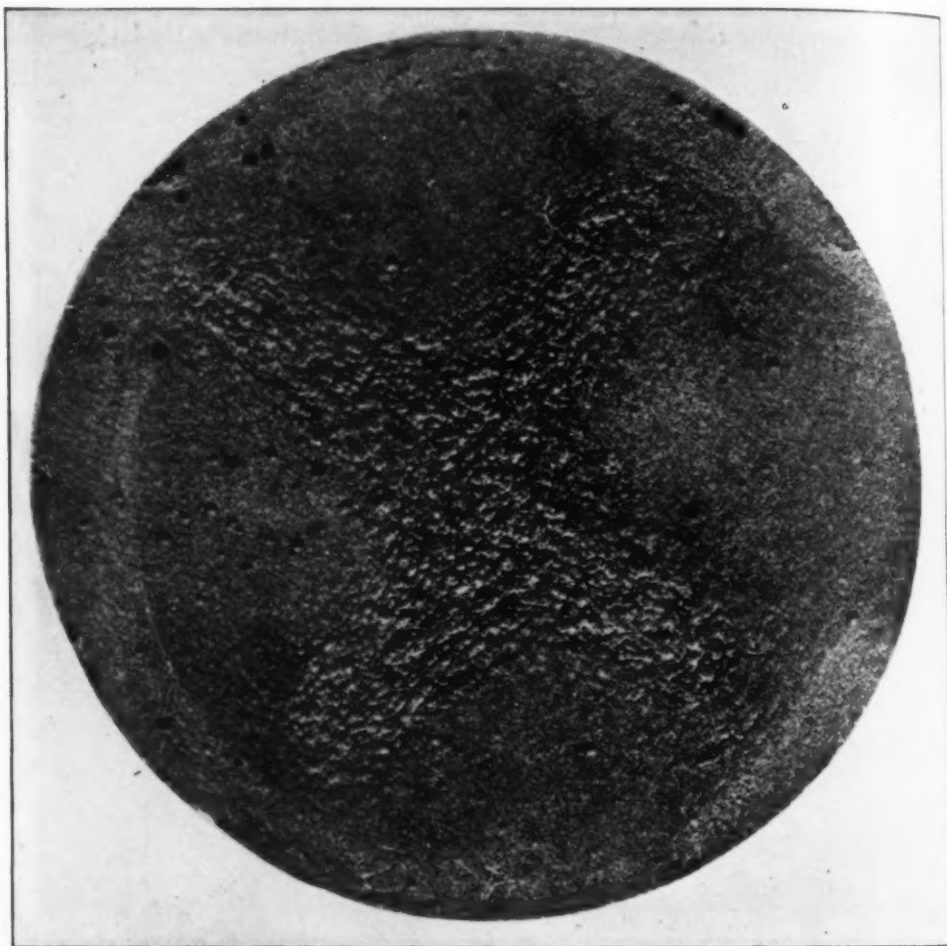


Fig. 38—Deeply Etched Specimens Showing Internal Defects Which Usually Result in Hammer Piping or Splitting During Forging. Mag. 1.50x.

in size in any direction. No form of heat treatment would break up the condition shown. Further forging down to a black heat would break it up into a finer size. Such growth has not been experienced in alloys of under 13 per cent chromium.

The microscope added further to the division which had roughly been made between alloys of 13 per cent chromium and under, and of alloys of over 14 per cent. It also offered a suitable explanation for the division. Figs. 20-21-22 show the uniform structure obtained in quenching and drawing alloys of under 13 per cent

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chromium. Quenching these alloys from 1750 degrees Fahr. or air cooling from forging heats of 1950 degrees Fahr., gave uniform martensitic structure. Repeated heatings to 1950 degrees Fahr. failed to alter the conditions. Fig. 24 covering a 14.26 per cent chromium alloy, introduces a different condition. Fig. 24-A shows the structure when cooling from a forging heat, or as oil quenched from 1750 degrees Fahr. Instead of being uniformly martensitic, it is composed of two constituents, an irregular bright appearing constituent, and a darker constituent essentially martensitic. "B" shows the material annealed and "C" as quenched and drawn. The bright irregular grains remain unchanged apparently through such treatments. Heating to high forging temperatures or numerous heatings to lower temperatures causes the grain growth shown by Figs. 28-29-30. These enlarged grains appear to be entirely stable and no amount of heat treatment will destroy them. These enlarged grains appear to be a growing of the bright irregular grains, absorbing the martensitic constituent, and continuing stable after such growth. With increased chromium content above the 14.26 per cent, the temperature at which this transformation or growth takes place is greatly lowered, and a single application of heat is sufficient to cause grain growth of a serious nature.

Thus chromium content is of great importance in the control of physical properties, of microstructure and in the forming of the materials to their final shape. At some point near 14 per cent chromium content, the alloys become dissimilar in many respects. The division at this point was made originally from tensile test results and practical experience with working the alloys, and later partially explained by microscopic examination. It was indeed gratifying to find confirmation and further explanation in the splendid paper by Bain (10) presented before this Society last January, in which by carefully controlled investigation he made a division in low carbon chromium-iron alloys at 14 per cent chromium content, and explained the special constituent and grain growth by the delta iron theory.

Relative to the effect of copper, three steels are shown, with 0.83, 0.80 and 1.06 per cent copper content, and the indications are that if any value or benefit is derived from the copper addition as regards increased resistance to corrosion, it is secured at no loss in

physical properties and no trouble was experienced in the forging of the materials.

Relative to the effect of silicon, three steels are shown with 0.68, 1.05 and 2.44 per cent silicon content. The first two are in connection with high chromium and thus a variable is introduced. The lot containing 2.44 per cent, however, contained but 12.92 per cent chromium, and may be safely compared with alloys of similar chromium content and low silicon. The material has lost all ability to harden or improve its strength, although it apparently can be treated to give good elongation and reduction of area, but with the impact values remaining at zero.

Data has not been included on stainless iron containing nickel of higher than 0.59 per cent, but additions of higher nickel appears worthy of passing comment. Clarke (11) contends that the addition of nickel to steels where chromium predominates does not improve either the stainless properties or the physical properties. There is some evidence that the addition of from 1 per cent to 3 per cent of nickel to low carbon chromium-iron alloys has considerable effect on the physical properties. Apparently greater hardness and strength are possible, the hardening and annealing ranges are reduced several hundred degrees Fahr., and slow cooling in the furnace results in nearly as high physical properties as oil quenching or air cooling. There are many applications where such a material could be used to advantage.

CONCLUSIONS

From the data presented, it is apparent that this group of low carbon chromium-iron alloys makes a most interesting and valuable addition to the field of engineering and industrial materials. By reason of patent restrictions and other arrangements, the alloys have appeared commercially in various grades and compositions. There have been staunch supporters of low chromium, of intermediate chromium, of high chromium content, with and without additions of silicon, nickel and copper. Data has been published based on particular grades, and the impression often prevails that such data applies to stainless iron in general. The virtues of some grades have been held up and compared with the vices of others. Commercial ranges of chromium often embrace alloys of under and over the 13-14 per cent natural division, for the same grade, and

uniform results could in no way be secured with such ranges.

The data here presented would indicate that each of the various grades has its use, each may have its shortcomings. A particular grade or composition may serve admirably for one purpose, but might not serve so well for another application as one of the other grades. For example, for a given application requiring high physical properties and where maximum resistance to corrosion is unnecessary, the low chromium material would serve best. On the other hand, for an application requiring maximum resistance to corrosion, with little or no concern as regards physical properties, the high chromium with silicon addition would probably serve best. A careful consideration of each application, the method of fabrication, the physical properties required, the degree of corrosion resistance and the nature of the corroding agent, should be given, as each of these matters has an important bearing in the proper selection of these materials.

ACKNOWLEDGEMENTS

In closing, the writer would express his thanks to H. T. Herr, vice president of the Westinghouse Electric and Manufacturing Company, for permission to publish these results; also to express his appreciation of the helpful assistance of the several members of his laboratory in carrying out the work; and his appreciation of the cooperation of a number of the manufacturers of the materials used.

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Written Discussion:—By Jerome Strauss, Navy Yard, Washington, D. C.

More valuable data has been included in Mr. Mochel's paper concerning that class of corrosion resisting steels which is likely to attain the most widespread use than has hitherto appeared in print in a single publication, and the author is to be complimented upon covering a large field so concisely.

Comment concerning that misleading practice of reporting yield point as elastic limit is indeed timely, particularly in the case of these steels in which small changes in heat treatment often results in a change from a metal giving a sharp "drop of the beam" to one in which the stress-strain curve is such as to make the observation of, or even the existence of, this phenomenon questionable. It is gratifying to note the use of definitions of certain terms, but a question is raised as to whether these values may be described as "methods of reporting elastic limit" or whether it is not best to consider them "strength properties of the materials, associated with the range of elastic movement." It is further to be regretted that once having defined these terms, the author did not use them throughout his further discussion. His statement that "in general, Johnson's limit is referred to when the term 'elastic limit' is used," leaves one in some doubt as to just what each subsequent reference to "elastic limit" really means. For instance, in Figs. 6, 7 and 16 the term "proportional elastic limit" and "Johnson elastic limit" have been employed, although neither one, as such, is defined. On the other hand, in Figs. 3, 5, 8, 10, 12 and 17, the term "elastic limit" is the only one appearing on the graphs and a question arises as to whether this is actually "elastic limit" or "Johnson limit." This confusion of nomenclature is regrettable particularly since the author early in the paper leaves the reader to believe that he is carefully avoiding the misleading practices which have heretofore so greatly confused the literature on the properties of metals.

The statement is made that the Johnson limit "did not appear so subject to radical variations in its ratio to ultimate strength and other properties," and therefore has been used in preference to proportional limit or other associated strength factors. The question may properly be asked whether relationship to tensile strength is any criterion of the utility of any measure of elastic properties or whether the likelihood of

permanent set or the amount of permanent set under given conditions of loading is not a far safer index.

In the general discussion of the methods of testing the author states "curves — often curve from the start and it is difficult to locate the proportional limit, but by following the longer method of determining true elastic limit a definite value can be determined." The writer is in full agreement that the determination of proportional limit is often most difficult. However, it is to be concluded from this sentence in the paper that the curves of extension under load differ according to whether a set curve is or is not obtained at the same time; or is this really another indication of confusion in nomenclature? The writer has observed wide differences between elastic limit on the one hand and proportional limit and proof stress on the other hand. In general these wide differences will be found in specimens containing considerable internal stress due to either no tempering or short-time low-temperature tempering. In such cases the proof stress is often lower than the proportional limit.

Mr. Mochel finds a temperature of 1750 degrees Fahr. as the most suitable one for quenching these steels, based upon the results of mechanical testing. The writer desires to ask whether this temperature also produces the maximum of resistance to the corroding media which the author employed in his tests. The differences in resistance to corrosion with change in heat treatment are, of course, less than in alloys containing higher carbon content, but the point is nevertheless of much interest.

Mr. Mochel has noted that extreme softness results in these low-carbon chromium steels upon slow cooling from 1800 degrees Fahr. Has he observed any difficulty in subsequent heat treatment of such high-temperature-annealed material due to inability to obtain in the usual short time at the quenching temperature, complete solution of the carbides separated in annealing?

The sharp drop in strength properties between 1000 and 1200 degrees Fahr. has been previously reported by the writer and others. In some chromium steels of medium carbon content the writer further observed a sharp decrease in resistance to corrosion for this same range of tempering temperature. Has Mr. Mochel observed any such phenomenon in any of the low carbon alloys which he has studied?

The author has covered in an excellent manner the hardening of certain compositions due to other than slow cooling from above certain minimum temperatures and also to the grain growth in other compositions when heated for long times or repeatedly heated above certain temperatures. It should be pointed out that these phenomena are of great importance in riveting and in welding operations. Studies are now in progress to determine the most satisfactory methods of handling various compositions in processes of this character.

Jerome Strauss.

Author's Reply

The author appreciates the comments by Mr. Strauss. His criticism of the

failure to use in the discussion, the terms already defined, is well taken. We considered the terms "proportional limit" and "proportional elastic limit" as synonymous; likewise "Johnson limit" and "Johnson elastic limit." The statement to the effect that where the bare term "elastic limit" was used, "Johnson limit" was referred to, should leave no question.

The statement "curves—often curve from the start and it is difficult to locate the proportional limit, but by following the longer method of determining true elastic limit a definite value can be determined" was merely intended to bring out the fact that the materials would show a definite value of true elastic limit even though the stress-strain diagram was curved from the start, thus possessing no proportional limit.

The question as to whether the temperature of 1750 deg. Fahr. for quenching, produces maximum resistance to corrosion, and as to whether or not a sharp decrease in resistance to corrosion occurs with the sharp decrease in strength properties between 1000 and 1200 degrees Fahr. draws, will probably be answered by work in progress. It is not expected that the great differences in corrosion resistance shown by the higher carbon alloys, will be experienced with these low carbon alloys.

The annealing from 1800 degrees Fahr. for extreme softening has been used but little for materials to be subsequently heavily cold worked, and not later to be quenched and drawn. The author therefore cannot answer from his own experiences. It has, however, been brought to his attention, that grain growth and loss of ability of give maximum hardness upon subsequent treatment, has been experienced on materials annealed at high temperatures.

ON ELECTRIC STEEL MELTING

BY BIRGER EGEBERG

Abstract

This paper deals with the problems met with in the making of high grade steels, especially tool steel, in the electric furnace. A comparison is drawn between the acid open-hearth, the crucible and the basic electric furnace as regards deoxidation. It emphasizes the national economic value of the electric furnace, in addition to many other advantageous features, and discusses the weak points of the furnace and some defects in electric steel which as yet are not fully under control.

INTRODUCTION

IN Nature, iron occurs chiefly in the form of oxides but never as metallic iron. In order that these oxides may be useful in the making of metallic materials they must first be chemically reduced. All iron and steel is therefore an artificial product, the making of which is based upon the chemical reaction between iron oxide and reducing agents at some suitable temperature.

Theoretically, the separation of iron from oxygen is simple. The iron oxides need only to be brought in contact with an agent which under certain conditions has a greater affinity for oxygen than it has for iron. For example: by mixing iron ore with finely divided metallic aluminum and igniting the mixture at one spot, thus heating the mixture to a temperature that will start the reaction, a terrific heat, more than sufficient to melt the mixture, will be developed, due to the violent reaction of the aluminum with the iron oxide. The necessary oxygen is taken from the iron ore and the resulting product is metallic iron and a slag consisting chiefly of aluminum oxide.

In the iron and steel industries, however, the problems encountered are not so simple. In fact, the exact reactions are to a large extent unknown. The reason for this is that iron ores contain many impurities, in addition to those of the furnace lining, all of which take part in the reaction. Furthermore, the iron

A paper presented before the Buffalo Sectional Meeting, January, 1926. The author, Dr. Birger Egeberg, member A. S. S. T., is metallurgist, Halcomb Steel Company, Syracuse, N. Y.

and steel industry must use methods which are not only chemically but also economically feasible. For practical purposes these factors and methods exclude all reducing elements except carbon. Being soluble in molten iron carbon forms an alloy with the iron. At the present time, the direct reduction of iron ore to steel has only theoretical interest, although the future may change the situation.

The process of steel making commonly used involves two steps:—

- (1) Production of pig iron.
- (2) Converting pig iron (and scrap materials) into steel.

It is only with the second step, the steel making part, that this paper deals and especially in regard to some features of electric furnace practice.

ADVANTAGE AND ECONOMICAL VALUE OF THE ELECTRIC FURNACE

The electric furnace was introduced in the year 1900, about the same time that alloy structural steels were brought to public attention. The demand for these steels originated chiefly in the development of the automobile industry creating new requirements as to the physical properties of materials of construction. The demand, the steels, and the furnace to make them in, all developed at the beginning of the 20th Century and it is evident that the electric furnace could hardly have had a more favorable start. It was in meeting this new demand for alloy structural steels both as regards quality and tonnage that the electric furnace found its most valuable application. This is said notwithstanding the large amount of tool steel that is made in the electric furnace at present. The crucible process could, however, have continued to take care of this part, whereas the alloy structural steels, demanding a higher quality than that usually obtained from the open-hearth furnace, would have been impossible to produce in the crucible, because of the large tonnage required and also on account of the higher cost.

Besides tonnage, quality, and price, there is a fourth factor that brings the alloy structural steels into the natural domain of the electric furnace, namely, its capability of making steel with low alloy losses. The author is here touching a point, the importance of which, he thinks, is not realized to the extent it

ought to be, namely, the great economic value of the electric furnace. Our resources of alloys are not unlimited. At present, we are just at the beginning of the "alloy steel age," it being practically only twenty-five years old. The alloy steels will, no doubt, be continued to be developed as heretofore and mining scientists are engaged in figuring out how long our present ore resources will last.

We may find new and rich ores, but on the other hand, nobody knows what kind of highly alloyed steels will be developed. In late years the consumption of stainless steel and stainless iron containing 14 per cent chromium has increased in large proportions. Metallurgists are working on the problem of producing stainless iron directly from chromium ore. It is estimated that the price thereby would be greatly reduced, making it feasible to utilize this material for the hulls of sea-going vessels and many other industrial applications, which would lead to a heavy demand for suitable chromium ores. The development of the austenitic manganese steel, as well as the lower alloyed chromium-vanadium and molybdenum steels, should not be neglected. Although low in alloy content the steels are and will be made in greater tonnages, all of them containing elements that are easily oxidized. What would become of this tremendous amount of alloys were it not for the electric furnace? When remelted, most of it would go into the slag and be lost.

We then realize that the advantage of the electric furnace is not only to make high grade steels in large tonnage at reasonable prices, but its revolutionary achievement is one of international economy to recover the alloying elements from the scrap and to preserve our national resources.

The making of steel in the electric furnace, as well as in the open-hearth furnace, has been the subject of capable papers recently read before the members of this society. Therefore the intention of the present author is not to revive in detail the general procedure in manufacturing ingots and castings, but his chief object is to discuss certain reactions of the molten bath in connection with related properties in the finished hot deformed steel whenever such relation can be traced.

MELTING AND OXIDIZING

According to the general classification, the charge can be

melted with (1) complete oxidation, (2) partial oxidation or (3) without oxidation.

The writer believes the last mentioned classification of melting is misleading. It is true that the electric furnace can be operated so that little oxidation of the carbon and manganese takes place compared with melting down in an open-hearth furnace. This is the result of the non-chemical action of the electric current, whereas the heating gases of the open-hearth furnace always will have a highly oxidizing effect upon the charge.

When adding ore to the electric furnace, the oxygen content of the same ore will have a similar effect upon the bath as the heating gases in the open-hearth furnace, and if sufficient ore is utilized, a dead soft steel is obtained.

These different ways of manipulating have given rise to the classification above, which so far seems to be logical.

When molten iron is in contact with oxygen or with compound-carrying oxides (like rust on the scrap), it will be partially oxidized to ferrous oxide, which is soluble in the molten iron. At its melting temperature, iron can dissolve approximately 1 per cent FeO , at which concentration the saturation point is reached. If the oxidation is carried further, the excess ferrous oxide will separate from the iron and form a slag.

The electric furnace slag formed during melting is black and of an oxidizing nature no matter in which way the melting has been conducted. From all evidence at hand, we must therefore assume that the saturation point is reached in every case and that melting without oxidation is impossible.

The saturation point, however, may vary greatly according to the amount of deoxidizers left in the bath at the end of the melting down period. Silicon, and especially manganese, are excellent deoxidizers. When added to a molten oxidized bath they will react with the dissolved FeO and form SiO_2 and MnO , (or more likely, SiO_3Fe and SiO_3Mn), which largely will enter the slag, both being less soluble in the steel than FeO . This being the case it is natural that when present in not too small amounts during the entire melting down period, both manganese and silicon must be effective in preventing FeO from being dissolved in the bath, or this may be otherwise expressed by saying that the saturation point for FeO has been lowered. This is the reason

why a high manganese content in the charge is advantageous; obtained by additions of some austenitic manganese steel scrap or by adding ferromanganese with the scrap.

It is further evident that in order to keep down the saturation point of FeO in the bath, *that* melting process should be used which preserves a desirable amount of the manganese in the bath at the end of the melting down period. This consideration leads to the conclusion that melting with complete oxidation provokes a more highly oxidized metal as compared with melting without additions of ore. It should be borne in mind, however, that in the first case the resulting slag is drawn off before the white slag materials are added, giving them the opportunity to react directly with the metal, whereas in the other case, the white slag materials are mostly added directly to the slag prevailing at the end of the melting down period and this must be reduced before it can attack the oxides in the bath. The prevailing oxide slag is not well adapted to build up the following white slag and when based on these considerations alone it seems logical to assume that a process where no ore is used, but where the oxide slag is drawn off before adding the white slag materials, would be productive of the highest quality steel.

However, there are other factors that enter into this question as will be seen later. At this point, the author will only mention the importance of the personal adaptability of the melter himself for one or the other of the mentioned processes. The writer has seen only good results from oxidizing heats.

When melting with complete oxidation, all easily oxidized alloys will go into the slag and be lost, which is not in agreement with sound economy. It is therefore the custom when dealing with alloy scrap of the above mentioned character to melt with as little oxidation as possible and the other method is only practical when dealing with straight carbon scrap or with scrap-containing elements that are not easily oxidized (like nickel.)

During the melting down and oxidizing period, the phosphorus content will be lowered in much the same way as in the open-hearth furnace. The latter, however, has the advantage of the oxidizing effect of the heating gases, wherefore, it is a much better oxidizer than is the electric furnace. This is one of the reasons

why the electric furnace has not answered the expectations of 20 years ago.

DESULPHURIZING AND DEOXIDIZING

The electric current as a heating medium is of greatest advantage during the desulphurizing period. To eliminate any appreciable amount of sulphur is difficult or impossible with the older steel melting methods, because manganese sulphide is soluble both in the slag and in the bath. The MnS of the slag when in contact with oxygen from the furnace gases gives off the sulphur in the form of SO_2 . In order to establish equilibrium, a certain amount of MnS will pass from the metal into the slag and so forth. This process is, however, slow, especially as the steel grows more and more diluted with sulphur and is also dependent upon the sulphur content of the fuel.

A more effective desulphurization will take place when the sulphur is brought into a form soluble only in the slag and not in the bath. Such a form is calcium sulphide. However, the sulphur will only react with calcium as long as the slag is free from iron oxides, otherwise iron sulphide will form that is soluble in the bath. In the basic electric furnace, it is possible to maintain a slag free from iron oxides or any other oxides of the heavy metals whereby its lime content permanently will bind the sulphur, making a far reaching desulphurization possible.

This entirely new feature created new possibilities and great expectations. It was hoped that a purer metal could be obtained by first eliminating the phosphorus and afterward the sulphur, and thus give rise to a superior steel even when cheap raw material high in both phosphorus and sulphur were utilized. It is well known that this assumption proved to be wrong, and finally led to a deep depression in the development of electric steel which it took years to overcome.

It was soon established that the steel made was of a much inferior quality than expected. Steelmen at that period claimed the steel to be inferior not only to crucible melted steel, but also to open-hearth steel made in an acid-lined furnace.

When making steel by the last two methods, low phosphorus and low sulphur content were the points that were emphasized. When the chemically purer electrically melted steel did not show the expected results there certainly was reason to believe that the

detrimental effect of the above mentioned elements had been over-rated.

It is well known that the chemical composition, however ideal it may be, is an uncertain basis for judging the quality of a steel. The service the steel will render depends largely upon factors like structure, amount of slag inclusions, and so forth, which can be determined by the microscope.

However, there are many failures in service that cannot be accounted for either by the chemist or by the metallurgist. On the other hand, there are steels that, irrespective of some chemical or metallographic defect, have given wonderful service. It seems, therefore, most likely that the quality of steel, to some extent, is controlled by an unknown factor or by some factor to which the necessary attention has not yet been paid. The uncertainty established thereby has led to unreasonable close specification with regard to sulphur and other accessory elements.

In order to draw intelligently an exact and correct specification, it is necessary that we know all the factors that control the quality of the steel and further that methods are at hand by which these factors can be expressed in exact figures. It is evident that neither the chemical nor the metallurgical laboratories have as yet developed to such perfection. This will be realized when we consider that no exact figures can be given for the degree of deoxidation and for the volume of gas present in the steel nor any certain data on the nature and chemical constituents of the non-metallic inclusions. This last item may be of high importance depending largely upon whether the inclusions are malleable or not at regular forging and rolling temperatures. Further, the permissible amount of one impurity may largely be affected by variations in the percentage of other impurities.

The writer is aware that for some of the above mentioned factors different scientific tests are in existence which however have not been developed to such an extent that they are available for the works' laboratories.

Taking all this into consideration, it seems to the writer that certain specifications to some extent have developed faster than our knowledge and testing applications permit and such specifications may create more harm than good.

It is the writer's intention in the following pages to discuss

some factors in steel making known by experience to be of importance, but still remaining largely in the dark, due to lack of efficient testing methods.

The first electric tool steel made is said to have been very brittle in the hardened condition and to have developed a coarse-grained structure by very slight over-heating prior to quenching.

In making tests over a period of several years, the writer has found that well-managed melting departments of today occasionally make a heat with the above characteristics and it is still an established practice of several prominent steel makers on the European Continent to classify their heats according to tests that will disclose the above mentioned defects, if present in the steel. In conducting a large number of such tests, the writer has never found any relation between them and the phosphorus or sulphur content or any other chemical impurity commonly determined in the works' laboratory. Neither did the microscope reveal anything with certainty. The author, therefore, assumes that the origin of the above mentioned defect lies outside the reach of the present works' laboratory.

The older methods for making tool steels were the crucible and the acid open-hearth process and the writer relies upon the experience of others when stating that it was not until the basic electric furnace entered the field that the defect grew serious. As it has been found also in heats made from the very best of scrap, there is good reason to believe that the origin is found in one of the fundamental differences between the electric furnace and the other processes and it is also fair to believe that it is caused by some difference in the finishing rather than in the melting and oxidizing period. The general assumption is that the defect is caused by oxides or gases.

In the crucible and in the acid open-hearth furnace, a continuous reaction will take place between the silicon in the crucible walls or furnace lining and the oxides in the bath. Such a de-oxidation does not take place in the basic electric furnace where we have entirely to rely upon additions to the bath and the reaction between metal and slag.

It is evident from the above that the electric furnace has a smaller reacting surface per ton of metal than have the other two furnaces where, besides the contact between metal and slag, the

contact area between metal and furnace linings partake in the reaction.

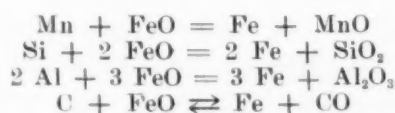
Franz Sommer has in *Stahlwerks Ausschuss Bericht*, No. 77, January, 1924, calculated that a crucible containing 80 pounds has a reacting surface of 3.6 square inches per pound of steel, whereas a 6-ton basic electric furnace only has a reacting surface of approximately 0.35 square inch per pound of steel. Taking into consideration, that the most commonly used electric furnace shows very little circulation in the bath, it is quite evident that the deoxidation necessarily must be a slow process.

The deoxidation in the older types of furnaces took place automatically and its importance was therefore underrated. When approximately twenty-five years ago the first electric furnace started operating, new ways had to be developed in order to obtain a well deoxidized steel. This is clear to us today, but it was not clear at that time, and it is therefore evident that a period of stagnation had to come. We have seen, that during this period, the rosy hopes and prospects of the electric furnace faded away until, due to the untiring struggle of men, it slowly worked itself upwards again to a position not quite as glorious as the old prospects, not absolutely independent of the scrap materials it is fed, but still to a unique position with regard to the four points: large tonnage, high quality, reasonable price and conservation of alloyed scrap mentioned in the introduction of this paper.

To come back to the deoxidation, it should be borne in mind, that the quality of the steel is not only dependent upon the extent to which deoxidation takes place, but it is also, to a marked degree, affected by the amount and nature of the deoxidation products that remain in the bath. It is not the writer's intention to go into any detailed discussion as to what extent slag and non-metallic inclusions affect the steel. He would, however, like to mention a certain defect, namely, woody structure, mostly found in alloy structural steels and which has not generally been attributed to the occurrence of non-metallic inclusions. In the writer's experience woody structure is always associated with inclusions. However, the inclusions visible under the microscope are hardly numerous enough to account for the stringy appearance alone, but sub-microscopical inclusions, originating from the products of deoxidation entrapped between the dendrites, acting as nu-

clei for pro-eutectoid deposits, may be the true cause of the defect. It is fair to assume that the deoxidation products must originally exist in a very finely dispersed form and as their melting point is very high, the small inclusions do not easily coalesce to larger particles, but have a tendency to remain so finely divided that they have a small chance to rise and enter the slag.

The deoxidizers utilized in regular melting practice are manganese, silicon, aluminum and carbon and in order to simplify, we will assume that the reactions take place in the following manner:—



We see that the first three reactions form solid oxides of manganese, silicon and aluminum, whereas by deoxidizing with carbon, a gas is formed. By using carbon as a deoxidizer, we would then avoid the dangerous formation of solid deoxidation products. However, it is not possible to deoxidize steel perfectly with carbon, because the reaction takes place in both directions, as indicated by the arrows. Metallic iron and ferrous oxide can, in other words, exist at the same time when acted upon by carbon.

To what extent the reaction goes to the right, depends on temperature and pressure, largely upon the partial pressure of the CO-gas in the furnace. If this gas could be removed, or the total pressure in the furnace lowered, it would, perhaps, be possible to deoxidize with carbon entirely. On this principle is based the idea of producing steel in vacuum or by removing the CO-gas formed through passing a current of neutral gas through the furnace.

The steel melter of today has, however, to be content with the regular electric furnaces in which carbon alone will not deoxidize the steel to the desired extent. However, it is possible to deoxidize the steel partially by carbon during the recarburizing period, thereby minimizing the amount of the solid deoxidation products.

In further consideration of the amount of deoxidation products left in the steel, it would be expected that this amount would be less when conducting the process so that the deoxidation takes place at the immediate contact surface between metal and slag.

whereby the solid products formed during deoxidation would only have a short distance to rise in order to be taken up by the slag cover. It is also of importance that the finished metal be given time enough to stand quietly in the furnace in order to rid itself of the rising impurities.

It is evident that the electric furnace has a great advantage in this respect over the open-hearth furnace. In the last mentioned furnace, whether acid or basic, it is necessary to do the final deoxidizing in the ladle or in the furnace shortly before teeming and the product formed by this reaction must largely remain in the steel on account of the short time it is given to rise. In the electric furnace it is possible largely to deoxidize by the slag and further to keep the steel for any desired length of time under a white cover, giving the deoxidation products an opportunity to rise to the surface.

Circulation in the bath, continuously bringing new portions of the metal to react with the slag, is a condition that would favor a complete deoxidation. It is unfortunate that only little circulation takes place in the most commonly used electric furnaces. Any mechanical stirring necessitates the opening of the furnace door, which is undesirable during the deoxidation period, due to the slag being exposed to oxidizing air. The furnaces built on the transformer principle—like the Roebling-Rodenhauer furnace and the Frick furnace—have in this respect, some advantage, because in them an active circulation takes place, and in the writer's experience, they produce an exceptionally high grade steel.

It is evident from the foregoing that the deoxidizing material utilized, may give rise to serious defects in the steel and it is an important part in steel making to see to it that the least possible amount of the deoxidation products mentioned remain in the steel when poured into the molds. It is pointed out that the electric furnace offers many advantages over the open-hearth furnace in this respect, but it is at the same time evident that we have still more ideal conditions in the crucible furnace where no deoxidizing additions at all are necessary. This is perhaps one of the chief reasons for the high quality of crucible steel.

Moreover, in the form of oxides, it is likely that oxygen exists in the steel also in the form of dissolved gas. The bulk of

the gas present in the molten bath is, however, found to consist of nitrogen and hydrogen. The hydrogen is readily given off during solidification and what remains in the steel is generally considered to be of little consequence. With regard to nitrogen, opinions are greatly divided. In the writer's experience the nitrogen content of basic electric steel may vary greatly. In straight carbon steels the content may be from 7 to 30 cubic centimeters per 100 grams of steel drillings corresponding to approximately $\frac{1}{2}$ to 2 cubic inches per $3\frac{1}{2}$ ounces of drillings, whereas an old nail from a Viking ship of 1000 years ago, was found to contain only $\frac{1}{5}$ cubic inches per $3\frac{1}{2}$ ounces of steel.

The contents are given in volume, although the nitrogen most likely was not totally in the form of gas, but rather in the form of nitrides.

The author's experiments on nitrogen in tool steel covers a period of several years and there has never been found any relationship between the nitrogen content and the quality of the tools.

He, therefore, believes that oxygen, whether in the form of dissolved gas or in the form of oxides, dissolved or precipitated, is responsible for most of those defects which today cannot be explained by the chemist or by the metallographist. In order to emphasize what has been said before, attention is called to the fact that steels of identical chemical composition made from the same kind of raw materials in an identical way by the same men and in the same furnace and given identical mechanical and thermal treatments, curiously enough may sometimes vary greatly in quality.

Discussion

H. M. GERMAN: I do not want any of our friends among this audience who are great users of steel, to go away with the opinion that the people who are making high quality steel today in the basic electric furnace do not realize the importance of eliminating oxygen, either in the form of oxides or gas, from the metal. As has been said, the quality of steel is dependent very largely upon the elimination of these impurities. Our best practice today is melting down under a partial oxidation. After the slag has been removed, which contains a large amount of iron oxide, a new slag is then built up. This slag at first is very heavy in lime content. I wish to call attention to the fact that not only is the composition of the slag important, but also the volume of the slag as well. After the lime slag has once been made, it is then turned, as we call it, by the addition of fine carbon, as in the form of coke dust, which will combine with the lime and form a carbide slag. Although we do not have a circulation, as some would like to have it, in the

electric furnace by keeping this slag on the metal for a sufficient time, we can carry the oxidation to a very extended point. This, I think, has been brought out by several of our metallurgists at previous times and as dwelt upon very strongly by Mr. Sisco in his treatise on the manufacture of electric furnace steel. Any one who attempts to add certain other alloying elements to steel, as, for example, chromium, before the bath is completely or almost completely deoxidized, does so at a very great risk, as there is a great tendency to form a double oxide of iron and chromium, which, when once formed, cannot be eliminated from the steel. I merely give this as a point to illustrate the necessity of eliminating the oxides before making the alloy addition. It is true we do not prolong the heat long enough to get a complete deoxidization but by making frequent spoon tests and judging the metal, we can tell when the safe point has been reached. At that point, ferro-silicon is added, which tends to combine with the remaining oxides and form silica. After the bath is quieted, then is the time to make alloying additions.

I emphasize this point, because the TRANSACTIONS of the Society go directly into the hands of the people who are handling the steel, and I want them to realize that the people who today are making quality steel have this point in mind.

Another point, we recognize is that after the steel has passed all our tests and is absolutely dead, there may be some included oxide present as a result from the additions of the silicon. Aluminum, I might say right here, is not used by our best plants in making high quality steel, either in the furnace or in the ladle. Before tapping, good practice is to hold the heat for a short time to allow the oxide to come to the top. Another precaution which is taken is to tap through a spout or tube, which is placed in the opening or tapping spout of the furnace. By this method the slag is held back so that the metal comes out and the slag follows. Against this may be argued that where there is practically no slag on top of the metals in ladle there is danger of oxidation. But very careful tests have shown that this is a small amount indeed. The making of steel does not stop there. After that has been poured in the ladle it has been found by judging the time it takes for metal to skim over in a spoon, one can, after several tests, determine how long that metal can be held in the ladle before being poured into the mold. That will, to a very large extent, control the tapping temperature, and by lowering the tapping temperature we lower the solubility of the metal and decrease the amount of gases which would be held in the steel.

A. H. D'ARCAMBAL: Mr. Chairman, high speed steel is being melted both by the crucible and electric furnace process in this country today. I would like to ask the speaker to say a few words, if he will, regarding the two methods of manufacture of high speed steel, whether one method gives better quality product than the other.

B. H. DELONG: One answer to Mr. d'Arcambal's question is that the narrow carbon limits given in high speed specifications as at present written are more easily met by the use of electric furnace for melting than with the use of the crucible process.

H. E. SMITH: It is not directly on the paper, but I was interested in the statement that when chromium was added before the bath was well deoxidized, oxide of chromium is produced, which is very difficult to remove. Supposing chromium scrap is in the charge, as it must be in some cases, will that not produce a similar condition?

H. M. GERMAN: The double oxides would be produced if chromium scrap was charged and iron oxides added to the bath as in making a slag off heat. When sufficient chromium scrap is on hand, the usual practice is to melt down under a lime slag with practically no oxidation and finish under a single slag. It is not necessary to add ore to the bath.

W. J. MERTEN: I would like to ask Dr. Egeberg if he has considered, when he mentions that these steels, both being comparatively of the same quality and being put into service, under similar conditions whether the performances have been different because of the difference of the stress concentration due to the effect or irregularity that might have existed locally and thereby caused such concentration and consequent different performance.

DR. B. EGEBERG: As I understand it, Mr. Merten, you mean that tools made from two heats of different quality?

W. J. MERTEN: Of the same quality.

DR. B. EGEBERG: Because the hardening of the tool was not exactly the same?

W. J. MERTEN: No, I do not mean that. I mean the defective portion or the impure portion of the material may have been located in the material at such a point that the stresses did not detrimentally affect the cutting portion of the steel in one case but failed the tool in another case where the location of much imperfection becomes serious.

DR. B. EGEBERG: I might mention in that connection that the special steel I had in mind when making my statements was rock drill steel. We followed a number of heats through making actual drill test on hundreds of drills from each heat in the customer's plant and such a test certainly ought to show what the heat is worth. Sometimes we found a heat that stood up extremely well; that would drill twice as much nearly as the average, and on the other hand a few heats showed a consistently low performance, in many cases it was not possible by any chemical or metallographic investigation to establish the cause. The origin of the defect I am referring to, is therefore, not as tangible as a local defect, like an impure portion, as assumed by Mr. Merten, nor is it due to any difference in the application of the stresses, because all tests were made on rock drills.

B. H. DELONG: May I express one further thought in reference to the term "quality" as applied to the manufacture of high grade steels. This particular term "quality" signifies to the user that parts made from the steel shall give satisfactory service, as has been suggested by the speaker's comments in reference to rock drills. It has been my experience that steels having very different properties and manufactured by radically different methods may prove of extremely high quality when used for different purposes. For instance, steel so manufactured as to be very suitable for the produc-

(Continued on Page 475)

THE DROP FORGING PROCESS

BY J. H. G. WILLIAMS

Abstract

Mass production of good quality at reasonable cost is made possible by applying the drop forge process in forging steel rendered plastic by heat. With the drop forging process it is possible to produce forgings in quantity which are duplicates of each other.

In this paper the entire process of drop forging is described from the inspection of the raw material to the finished product.

In general, a direct oil-fired furnace is best for heating steel for this type of work. The paper describes in detail its construction and installation.

The effect of heat and mechanical work upon the structure of steel is discussed in some detail.

The size of the hammer to be used is largely determined by the area to be forged. Tables giving hammer ratings and hammer production are presented.

The paper is concluded with an estimate of cost of producing certain types of drop forgings.

THE drop-forge process exists because with it it is possible to produce forgings in any quantity which are, practically speaking, duplicates of each other.

Any geometrical form of such shape which permits removal from the dies, may be forged, but it is not always economical to do so. For instance, round, square, hexagonal or other bar-shapes are forged more cheaply and accurately by the rolling process. Furthermore, the quantity may be too small to justify the expense of making the dies. Any plastic material may be drop-forged, but the process is commonly applied to steel rendered plastic by heat.

Metallurgically, drop forgings must be sound and homogeneous. They must conform to definite chemical restrictions, also to definite limitations in physical strength and must respond to certain heat treatments, and be machinable. Mechanically, the forgings must be true to size within tolerances, clean, and free from forging defects. From an economic standpoint drop forgings of good quality must be produced at a price low enough so that they

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will be purchased in preference to corresponding products made by competitive processes.

INSPECTION OF MATERIAL

Because steel bars include nearly all the raw material used for drop forgings, only hot-rolled steel bars are alluded to under this heading, although the methods described will apply in general to other materials.

Chemical Analysis

The mill analysis is checked with drillings taken from bars selected at random. For the ordinary grades of forging steel one check upon carbon, phosphorus, and sulphur is sufficient. The purpose for which the forging is intended governs the extent of the chemical inspection. Large expensive drop forgings, sold under definite guarantees to meet rigid physical tests, may justify checking the carbon content of each bar, with frequent checks upon predominant elements, or injurious elements. (See S. A. E. and A. S. T. M. specifications for taking the samples.)

Surface Inspection

When the bars are unloaded from the cars, they may be inspected visually for cracks, seams, laps, scabs, burned spots, excessive scale or rust.

Etch Tests

Thin slices may be sawed from the ends of bars selected at random and deep-etched in hot acid. (See Handbook, A. S. S. T., Section T-7.) Sound steel, after being subjected to this test, will present to the eye an even, homogeneous, slightly acid-eaten surface.

An outer rim of clean, homogeneous metal surrounding a core of spongy, deeply pitted metal, indicates segregation, the presence of foreign matter in injurious quantity. Blow holes, pipe, internal flaws and surface cracks are also revealed, if present. Segregation is checked by comparing the chemical analysis of the core with that of the rim. The presence of banded or dendritic structure is uncovered by this test. It is not good policy to reject material upon the basis of this test only. It serves as an indicator of the quality of the material. The effect of the deleterious factors should be confirmed by physical tests. If the steel will not meet the physical requirements of the finished article it is worthless.

Sulphur Prints

Sulphur printing is a quick, efficient indicator of sulphur segregation.

Macro Inspection

The amount of dirt in the steel is shown qualitatively. Ordinary grades of steel are never entirely free of foreign inclusions, but their presence in quantity will weaken the steel. Hence, if suspicions are aroused by the results of macro inspection, they should be confirmed by physical strength tests, upon the basis of which the material should be accepted or rejected.

Shear Test

The presence of pipe may be detected visually by examining the freshly sheared section of a bar. Hence, when the bars are sheared to length before forging, they should be examined.

Physical Tests

The results of these tests are positive, and a definite basis for the acceptance or rejection of material. Unfortunately, they are somewhat expensive, and require time. When any of the speedier tests indicate inferior material, the physical tests should be resorted to. Ordinarily, the tensile test is sufficient.

(See A. S. S. T. Data Sheets, Section V-17; also the S. A. E. Specifications.)

In the absence of physical specifications, the strength of the specimen may be compared with that of similar material in the "as-rolled" condition. Usually, physical requirements are specified for a definite metallurgical condition of the forging, such as normalized, or annealed, or heat treated in a specified manner. In such cases the test piece should be correspondingly heat treated. When, on account of the heavy cross section of the bar, it is necessary to draw down the size under a trip-hammer, so far as possible the conditions of heat and reduction which would prevail under the drop-hammer should be duplicated under the trip-hammer.

Depending upon the physical requirements governing the acceptance of the forgings, the tests should include the breaking strength, yield point, elongation, reduction of area, Brinell hardness number, impact value and fatigue value.

DIES

Material

For all ordinary work, a plain carbon, open-hearth steel containing 0.60-0.70 per cent carbon is suitable. The quantity of forgings to be made, or the excessive wear to be resisted, or the grade of steel being forged, may justify the use of alloy steel die blocks.

The superior steel for drop forge dies is made of carefully selected raw material, carefully melted and handled under such close supervision in all its subsequent fabrication that finally it is clean, close grained, free of foreign inclusions, occluded gases, and internal defects, and free of forging and cooling stresses.

Die blocks are supplied in the "annealed" or in the "treated" condition. In the annealed condition the plain carbon steel die blocks are 30 to 32 hard on the scleroscope scale; the treated blocks are 45 to 50 hard on the same scale. After forging, the blocks are sometimes heated above the critical range and permitted to cool in the air. In this condition they are sometimes termed "floor annealed."

Rough blocks usually have $\frac{1}{4}$ -inch allowance for machining.

DIE SINKING

Number of Impressions

The number of impressions is determined by the shape of the forging and the quantity of forgings required. A bar of steel of uniform cross section is to be converted by the die impressions into a shape of entirely different form, probably non-uniform in cross section. Hence a marked translation or movement of metal takes place in the impressions, causing heavy erosive wear, which tends to change the form of the impressions. The final blow struck by the die determines the size of the forging, and, if the wear has been extensive there may be an important dimensional difference between the first forging and the thousandth forging.

Obviously, in a short run (under five thousand pieces) it may be economical to save die expense by forging in one impression: while on a quantity run it is economical to use several impressions, to protect the finish impression against wear, and thus prolong the life of the dies. Ordinarily, the life of a pair of plain carbon steel dies is about 20,000 forgings.

Generally speaking, the impressions sunk are: a fuller, or edger; a roughing impression; and a finishing impression. The size of bar stock is selected on the basis of filling the largest cross section of the forging. Hence, the bar is entirely too large for the requirements of other portions of the forging, and the fullers are employed to effect the reductions. Fig. 1 represents good forging practice in the design of fullers.

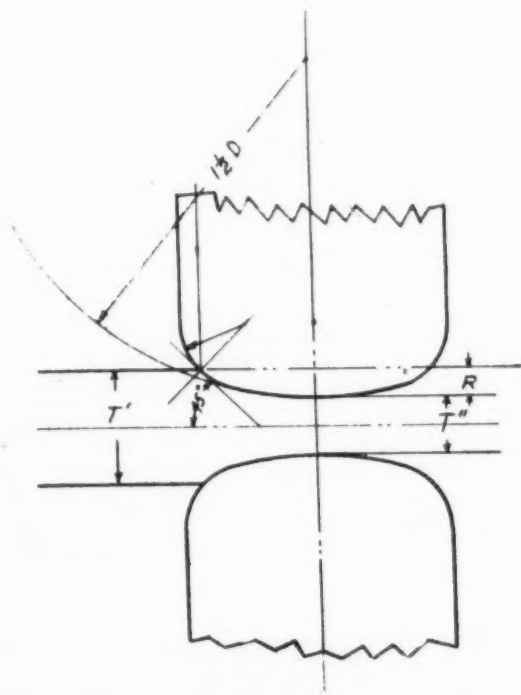


Fig. 1—Sketch Showing the Proper Design of Fullers Suitable for Good Forging Practice.

- T' = original thickness or width of stock
- T'' = final or desired thickness or width of stock
- R = reduction in width or thickness as effected by each fuller
- $R_{\max} = \frac{1}{4}T'$, or, one fourth the original thickness of bar
- D = length of draw
- $D = 8 \times R$

If 2-inch stock is to be drawn and reduced by the fullers, then the maximum reduction is to a thickness of 1 inch, and the maximum length of the fullers is 4 inches. By the use of fullers the forger roughly distributes the steel bar in masses to conform to the requirements of the forging.

Fullers are cut in the side edges of the dies. They are sometimes called "edgers." Edger impressions are more properly

impressions cut in the side edges for the purpose of locating masses with reference to each other, or for bending the bar.

The purpose of the roughing impressions is to mold the masses of metal into a form approximating the shape of the final forging. The edger impressions, if properly employed, enable the forger to place the blank between the roughing impressions with the masses of metal corresponding in position with the volume requirements of the forging. The principal forging action takes place in the roughing impressions, which are deliberately oversize to some extent, and the heavy erosive work of forming bosses, depressions, ridges, and shallows is carried out in such manner, that when this blank is placed in the "finishing" impressions the excess metal will flow outward into the gutter without the formation of forging defects. The purpose of the finishing impressions is to give the forging its final and true shape.

To sink a set of impressions in a pair of die blocks, the following general operations are necessary:

- | | |
|--|----------------------------|
| 1. Face, square one side edge with the face, shank. | 7. Sink edgers and fullers |
| 2. Square rear edge with the side edge, and with the face. | 8. Sink flash and gutter |
| 3. Layout | 9. Gate |
| 4. Sink finish impression | 10. Dowel |
| 5. Take lead cast | 11. Cut-off |
| 6. Sink roughing impression. | 12. Heat treat |
| | 13. Polish and grind. |

Operation 1 is performed on a planer. The blocks must be machined in pairs. A saving in time is made when several pair of the same size can be ganged. The following table shows the time required to plane and shank various sizes of annealed blocks:

Size in Inches	Time in Hours
6x6	4
6x8	5
7x7	6
7x9	7
8x8	7
8x10	8
9x9	9
9x11	10
10x10	10
11x11	12
12x12	14
13x13	16
14x14	18
15x15	20
16x16	24

The top face should be planed sufficiently smooth to permit a legible drawing to be scratched upon its copper plated surface, with the minimum amount of flat filing. The edge or side which is planed square is the edge which will be on the forger's left side when the blocks are placed face to face in the hammer.

Shank sizes vary among the various drop forge shops. In most cases they are too small. The larger the shank, the more firmly the keys hold, and the less the liability to "rock" the die when performing heavy edger work, with less tendency to fracture the shank. For hammers rated at 1000 pounds and under, the shanks should be about $1\frac{1}{2}$ inches deep and 4 inches wide; and the larger hammers should hold dies with shanks about 2 inches deep, and 6 inches wide. Although most forgings are of such shape that the blocks are planed with flat faces, there are many forgings containing bends or angles which require corresponding offsets in the face of the die blocks.

Operation 2 is the first operation performed by the die sinker, the previous operation usually being performed by a lower priced workman. A shaper is generally employed.

Operation 3. See Draft, see Shrinkage. The two squared edges on each block constitute reference surfaces. That is, the layout upon each face is made with such reference to the squared edges that when the blocks are placed in the hammer face to face

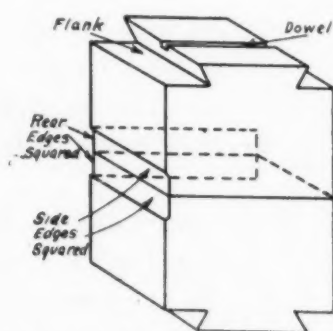


Fig. 2—Sketch Showing the Design of a Satisfactory Pair of Drop Forging Die Blocks.

with the edges in exact match, the layouts upon each face are in exact coincidence. Correspondingly, when the impressions are sunk with reference to the layouts, the cavities in each block enclose a form the exact duplicate of the forging desired.

Operation 4. A specially developed type of vertical spindle

milling machine is employed for cutting or sinking the impressions. The cutters are either two-lip or four-lip. For "hogging" out metal the two-lip cutter is probably faster, but it imposes a greater strain upon the spindle bearings. For finishing work the four-lip cutter is preferable. The die sinker guides the tool to the outside draft line, using a depth gage to prevent cutting the impression too deeply. The cutter is tapered to the angle required by the forging, but not less than the minimum draft, which is generally 7 degrees. Bosses and projections are sunk first; and then the various connecting channels.

It is good policy to sink the finish impressions before starting the remaining impressions. Then, if the customer makes changes after receiving the lead cast, they can be incorporated and a new lead cast submitted for approval. After approval is obtained, the remaining impressions may be sunk. It sometimes happens that drastic changes in design are made which require new impressions. In such cases, new finish impressions are sunk in the space reserved for the roughing impressions, and after approval of the lead cast, the old finish impressions can be changed into roughing impressions, and the necessity for replanning the die blocks avoided.

Formed cutters are often required. Semi-circular impressions are sunk with cherrying attachments. Square or nearly square corners are cut by hand. Shapes not possible to obtain by the use of revolving cutters are cut by hand with the use of "types." These are hardened steel models of the shape desired. They are blued, and driven into the roughed out impression and the blued projections in the impression chipped or scraped until the type fits true.

Operation 5. The blocks are clamped together, face to face, with the edges in match. Molten lead is poured into the enclosed cavity through a small gate. In the case of thin sections or intricate shapes it may be necessary to heat the blocks slightly in order that the lead may run into all parts of the impressions before solidifying.

In checking the lead cast, suitable allowance must be made for the shrinkage of the lead. Furthermore, it must be borne in mind that the lead cast, minus its shrinkage, is the shape of the hot forging, and an allowance must be made to obtain the size of the cold forging.

Portions of the lead cast may be locked against cooling shrinkage. Referring to the sketch, Fig. 3, it is apparent that the distance "A" is locked against shrinkage by the collars.

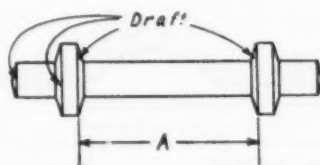


Fig. 3—Sketch Showing What is Meant by Draft.

Operation 6. Not only is the roughing impression used to prepare a blank which imposes a minimum amount of wear upon the finish impression, but it also must be shaped with reference to the manner in which the excess metal will flow. The excess metal is supposed to flow outwardly toward the gutter, but it actually flows in other directions as well. If the roughed blank presents

Table of Lead Shrinkage

Dimension	Shrinkage in Inches
$\frac{1}{4}$	0.0030
$\frac{3}{8}$	0.0045
$\frac{1}{2}$	0.0060
$\frac{5}{8}$	0.0075
$\frac{3}{4}$	0.0090
$\frac{7}{8}$	0.0105
1	0.0120

a deficit of metal to any portion of the finish impression, the metal will flow in that direction if it happens to be the path of least resistance. In such a case there is likely to appear on the final forging a lap of metal called a "cold shut." There may be an excess of metal in the roughing blank and yet be a flow of metal from one portion of the forging to another. Hence, in making the roughing impressions the die sinker, so far as possible, must anticipate these undesirable possibilities and provide against them by supplying more metal to create a pressure which will force the metal outward, or to provide greater draft, or so ease up the slopes that the path of least resistance will be outward.

The factors entering into the behavior of the metal in the impressions are the result of unequal rates of cooling, resistance to flow of varying nature in various parts of the impression, the forging temperature, and the speed of forging. Their analysis is indeterminate. Experience is the principal guide.

When a hot bar of steel of uniform cross section is struck

between impressions, shaped somewhat as shown in the sketch of Fig. 4, the metal is more or less gathered into the impressions, and, within limits, more metal is gathered into the impressions

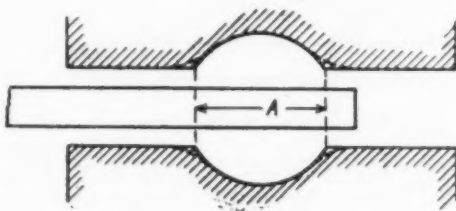


Fig. 4—Sketch Showing a Bar of Steel Between Forging Dies. Usually More Metal is Gathered Into the Impression than is Shown by the Limits Indicated by A.

than is contained in the length "A." To some extent the die sinker is able to modify this gathering effect by more or less rounding the corners, as indicated by the dotted lines.

Making allowance for this gathering effect, it may be stated that the area of any section of the roughing impressions is less than the corresponding section of the bar stock, and greater than that of the corresponding section of the finish impressions.

The pressure exerted by the dies should force the excess metal outward. In every forging of varying sections the metal tends to flow in other directions. With the first few blows the pressure of the high portions of the impressions is exerted against the bar stock, and the metal is free to move in nearly any direction. When the die impressions are filled, and it remains only to strike them until the dies hit face to face, the excess metal must move through the flash and into the gutter. With this outward movement of metal are carried into the flash, minor laps and joints of metal. If they are not pushed clear of the body of the forging, a defective forging is the result. The die sinker is able to direct this flow of metal in several ways; any or a combination of them he uses as his judgment dictates. He may provide extra metal in the roughing impression by enlarging it somewhat; he can make the roughing impression somewhat shallow, and let some of the metal be driven back in the finisher; he can, to a certain extent, release resistance to flow by increasing the thickness of the flash.

Operation 7. The foregoing remarks also apply to the edgers. As implied by the name, the edgers are cut in the edges of the

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blocks. Hence, one side is open, and to obtain a symmetrical reduction in the stock, it must be given a quarter turn after each blow, "rolled," in shop terms.

Operation 8. The web of excess metal surrounding the forging is called the "flash." As a matter of fact, it consists of two portions, the thin web of metal adjoining the forging, which must be cut by the trimmer dies, and the thicker part of the web, called the "gutter," which really contains the bulk of the excess metal.

There is no set rule for the thickness of the flash; if made too thin, it will chill too rapidly during the forging period, and require additional blows to force the excess through, and if made too thick, will not only impose extra work upon the trimmer dies, but may even permit such easy exit of metal from the die impressions, that not enough will remain to fill the impressions in all parts.

Operation 9. The size of the gate is a matter of judgment. If the forging is to be trimmed cold, the trimmer dies must shear the gate, and hence it should be as small as practicable. The gate almost invariably is placed at the heaviest end of the forging.

Operation 10. The upper die only is doweled. There is no standard applying to dowels, each forge shop using its own standard.

Operation 11. The cheapest way to make the cut-off is to use the acetylene torch and cut a shear knife on the rear right hand corner of each block. When the edge wears out, it may be built up again by means of the torch.

Operation 12. Referring to plain carbon die blocks, they should be hardened from 1425 to 1450 degrees Fahr. in water, and drawn to about 500 degrees Fahr.

The old practice of heating to a good cherry red in a coal fire, in spite of its many dangers, at least had the merit of not decarburizing the surface of the steel. The heat treatment is a simple one. The blocks must never be loaded into a furnace which is above 700 degrees Fahr., and preferably should be loaded into a cold furnace. The blocks should be heated slowly, at a rate not exceeding one hour for each inch of least dimension. The flame must not impinge upon the block. The more time taken to heat the block up to 1000 degrees Fahr., the less the danger of cracking the block. The furnace atmosphere should be neutral. It is good policy to place the block face down on a pan of carburiz-

ing material in the heating furnace to protect the faces of the impressions from decarburization. The metal is not heated hot enough nor long enough to become casehardened to any noticeable extent.

The placing of the die blocks upon a piece of board or in a pan of charcoal is ineffectual. Marked cases of decarburization have been observed when charcoal was used.

When the block is heated to the desired temperature throughout, it is removed from the furnace and immersed face down in a tank of cool water. Under no circumstances should the water be allowed to exceed 100 degrees Fahr. The water should be actively circulating, and the die blocks should be directly over the geyser.

After a few seconds' immersion, the block is withdrawn until only two to three inches of the block is in the water.

It is at this point that the skill and experience of the die hardener enters. The die is supposed to be hardened without distortion. The amount of distortion is controlled by the rate of cooling of the shank, and portion of the block not immersed in the water. This control is obtained by regulating the amount of cooling water poured upon the top and sides of the block, and this regulation is a matter of judgment, based upon the general dimensions of the block, and the area and depth of the impressions.

Bosses and projections are liable to crack during the hardening operation. Hence, just before immersing it is good practice to cool these parts at least to a black heat, either by using a swab soaked in heavy oil, or a cake of cheap laundry soap.

The drawing operation is best performed upon a hot table, or plate, for the reason that by placing the die block upon the table, shank down, and allowing the heat to soak through to the face, a block is obtained which is progressively softer from the face toward the shank.

The blocks are tempered immediately following the hardening operation. In fact, there should be considerable residual heat left in the blocks after hardening, say enough to produce a temperature of 150 degrees Fahr. The blocks should heat slowly on the hot table, at a rate of not more than one hour for each two inches of thickness. The top face, previously sandpapered until bright, is closely watched, and the block moved around until the surface is a deep purple, ready to merge into a blue. At this point the block is immediately removed, and placed face down

upon the ground to cool. Preferably, the face should be placed upon a loam bed, damp and cool enough to hold the temperature of the face of the block from rising above the temperature at the time of removal from the hot table. There is a strong tendency for the temperature of the face to increase before decreasing, because the body of the block is at a higher temperature than the face.

Operation 13. In spite of all the care taken in previous operations, the dies will have warped, usually only a matter of a few thousandths. They are ground true on the faces and flanks, and if, in this process, the size of the impressions is changed, they must be scraped until back to their original dimensions.

Size of Blocks

The size of the die blocks is governed by the size of the piece, and the number of impressions. The area of the "beating" surface should occupy about one-third of the surface.

For each weight of hammer there is a minimum size of die block which may be safely used. If too small, the block will be driven into the shoe, spoiling the shoe for any other die, and may break the block itself, orpeen it down.

The minimum sizes are listed below:

Weight Hammer, in Pounds	Size Die Block (Minimum) Inches	Stroke in Feet
600	6x 6x6	3.2
800	7x 7x7	2.7
1000	8x 8x8	3.75
1200	8x 8x8	3.5
1400	9x 9x9	3.3
1600	9x 9x9	3.3
1800	9x 9x9	2.8
2000	10x10x10	3.1
2500	11x11x11	3.3
3000	11x11x11	3.3

Draft

The impression must be wider at the surface of the die, than at the bottom, without any undercuts, by an amount not less than 7 degrees. This taper is called the draft. It is possible to use less draft, by very careful workmanship, by the removal of every trace of tool marks, and polishing the sides of the impression. Internal surfaces, such as bosses and projections, upon which the hot metal tends to shrink, are given even greater draft, 10 to 15 degrees.

Inasmuch as the tool is guided by the outline drawn upon the surface of the block, the outline must contain the allowances for machining the forging, and also for the draft. Undercut surfaces are prohibitive. The draft is applied only to surfaces which would otherwise be vertical surfaces in the impressions. That is, a surface normally sloping or tapering from the bottom of the impression to the top surface of the die by an amount exceeding 7 degrees does not require the addition of 7 degrees more draft. The draft allowance to be added to vertical surfaces of various depths is shown in the accompanying table:

Table I
Draft Angles for Die Sinks

	$\frac{1}{32}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
3°	.0016	.0033	.0049	.0066	.0098	.013	.016	.020	.023	.026	.033	.039	.046	.052
5°	.0027	.0055	.008	.0109	.016	.022	.027	.033	.038	.044	.055	.066	.077	.087
7°	.0038	.0077	.0115	.015	.023	.031	.038	.046	.054	.061	.077	.092	.107	.123
10°	.0055	.011	.0165	.022	.033	.044	.055	.066	.077	.088	.110	.132	.154	.176
12°	.0066	.013	.020	.027	.040	.053	.066	.080	.093	.106	.133	.159	.186	.213
15°	.008	.017	.025	.033	.050	.067	.084	.100	.117	.134	.167	.201	.234	.268
20°	.011	.023	.034	.045	.068	.091	.114	.136	.159	.182	.227	.273	.318	.364
25°	.014	.029	.044	.058	.087	.117	.146	.175	.204	.233	.291	.350	.408	.466
30°	.018	.036	.054	.072	.108	.144	.180	.217	.253	.289	.361	.433	.505	.577

Shrinkage

An allowance must be made for the shrinkage of the hot metal. Scales graduated on the basis of $\frac{3}{16}$ inches shrink per foot are used. That is, a scale $12\frac{3}{16}$ inches long is graduated into 12ths, each 12th into halves, quarters, eighths, sixteenths, and so on as desired. In the case of long forgings, of small section, which are forged, hot-trimmed, and restruck, a shrinkage of $\frac{5}{32}$ inch per foot is sufficient. This is because the forging is at a comparatively low temperature when the final blow is struck.

Allowance for Forging Tolerances

Drop forgings are not exact duplicates. Due to the wear in the dies, irregularities in forging temperatures, and rate of forging, and the variable factor in the drop forger's operations, there is a non-uniformity in size, which requires some allowance. In

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the absence of definite standards, the following tables are a guide:

Table II—Cam Shaft

(See Fig. 5)

Finish Limits—A $\pm \frac{1}{16}$ 91%; $\pm \frac{1}{8}$ 9%
 Finish Limits—B $\pm \frac{1}{8}$ 83%; $\pm \frac{1}{16}$ 9%; $\pm \frac{3}{32}$ 4% miscellaneous 4%
 Forging Limits—A $\pm \frac{1}{16}$ 89%; $\pm \frac{3}{32}$ 7%; miscellaneous 4%
 Forging Limits—B & C — 0 — 0 — 0
 Forging Limits—B & C $\pm \frac{3}{32}$ 83%; $\pm \frac{1}{8}$ 4%; $\pm \frac{1}{16}$ 9%; miscellaneous 4%

Table III—Axle

(See Fig. 6)

Forging Limits—A $\pm \frac{1}{16}$ 74%; $\pm \frac{1}{8}$ 24%; $\pm \frac{3}{32}$ 2%
 Forging Limits—B $\pm \frac{1}{16}$ 76%; $\pm \frac{1}{8}$ 17%; $\pm \frac{3}{32}$ 7%
 Overweight—10% 89%; 15% 4%; 5 to 20% 7%

Table IV—Connecting Rod

(See Fig. 7)

Finish Limits—
 Variations Allowed—A $\frac{1}{8}$ 85%; $\frac{1}{16}$ 11%; $\frac{1}{32}$ 4%
 Variations Allowed—B $\frac{1}{16}$ 87%; $\frac{3}{32}$ 11%; $\frac{1}{32}$ 4%; Miscellaneous 4%
 Variations Thickness— $\pm \frac{1}{64}$ 63%; $\pm \frac{1}{16}$ 4%;
 $\pm \frac{1}{32}$ 17%; $\pm \frac{1}{32}$ — $\frac{1}{64}$ 9% miscellaneous 7%
 (Note: On a rod 10" between centers, A should be held $\pm \frac{1}{32}$)

Table V—Crank Shaft

(See Fig. 8)

Finish Limits—
 Finish and draft on thrust bearings $\pm \frac{1}{16}$ 67%; $\pm \frac{1}{8}$ 21%; $\frac{3}{32}$ 8%; miscellaneous 4%
 Shafts below 2" diameter—B $\pm \frac{1}{16}$ 81%; $\frac{1}{4}$ 13%; $\frac{1}{16}$ 4%; miscellaneous 2%
 Shafts between 2" and 3" diameter—B $\pm \frac{1}{4}$ 89%; $\frac{1}{16}$ 7%; miscellaneous 4%
 Shafts below 2" diameter—C $\pm \frac{1}{16}$ 83%; $\frac{1}{4}$ 10%; miscellaneous 7%
 Shafts between 2" and 3" diameter—C $\pm \frac{1}{4}$ 88%; $\frac{3}{8}$ 4%; $\frac{1}{16}$ 4%; miscellaneous 4%
 Flanged End—D $\pm \frac{1}{16}$ 78%; $\frac{1}{8}$ 13%; $\frac{1}{4}$ 9%
 Sides of Flange—E $\pm \frac{1}{4}$ 87%; $\frac{1}{8}$ 11%; $\frac{3}{32}$ 2%
 Sides and draft—F $\pm \frac{1}{16}$ 70%; $\frac{1}{8}$ 17%; $\frac{3}{32}$ 7%; miscellaneous 6%
 Forging Limits—
 Allowance on length—A $\pm \frac{3}{32}$ 87%; $\frac{1}{8}$ 11%; $\pm \frac{3}{32}$ 4%; miscellaneous 4%

Table VI—Gear

(See Fig. 9)

Finish Limits—
 Finish and draft, diameter under 8"—A $\frac{1}{8}$ 80%; $\frac{1}{16}$ 9%; $\frac{3}{32}$ 7%; miscellaneous 4%
 Finish on sides—B $\frac{1}{16}$ 72%; $\frac{3}{32}$ 21%; $\frac{1}{32}$ 7%; miscellaneous 4%
 Finish on sides—C $\frac{1}{16}$ 76%; $\frac{3}{32}$ 13%; $\frac{1}{64}$ 7%; miscellaneous 4%
 Forging Limits—
 Variations on diameter—A $\pm \frac{1}{64}$ 65%; $\pm \frac{1}{32}$ 21%; $\pm \frac{1}{16}$ — $\frac{1}{32}$ 7%; miscellaneous 4%
 Variations on thickness—B & C $\pm \frac{1}{16}$ — $\frac{1}{32}$ 8%; ± 1 4%; $\pm \frac{1}{16}$ 11%; miscellaneous 4%

Note—The tolerances are the result of a poll among forge shops.

FUELS

The average drop-forge shop contains less than twenty hammers, and is engaged upon job work. The intermittent character of the work, and the uneven demands upon fuel, scarcely justify the use of a producer gas installation.

The use of coal-fired furnaces is objectionable on account of the cinders and ashes, and the amount of stoking necessary to obtain uniform, steady heats.

The use of city gas is prohibitive, due to high cost, as a rule. Gas is a clean fuel, easily controlled, and as a source of heat is well adapted to forge work. A smaller air consumption is required

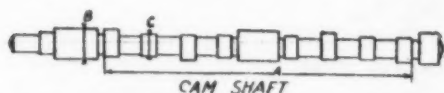


Fig. 5—Cam Shaft—Results on Finish Limits. See Table II.

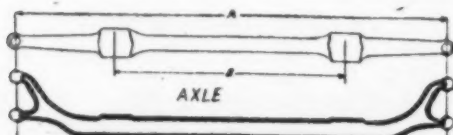


Fig. 6—Axle—Results on Finish Limits. See Table III.

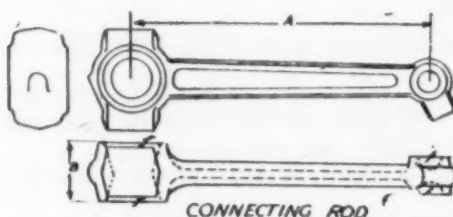


Fig. 7—Connecting Rod—Results on Finish Limits. See Table IV.

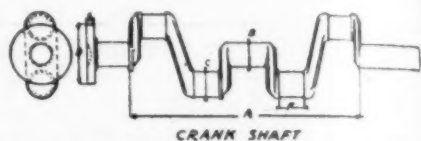


Fig. 8—Crank Shaft—Results on Finish Limits. See Table V.

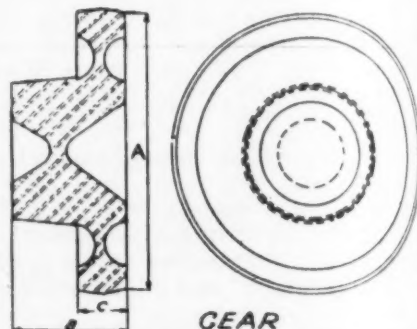


Fig. 9—Gear—Results on Finish Limits. See Table V.

Figs. 5 to 9 (Inclusive) Show the Allowance for Forging Tolerances in the Manufacture of Various Types of Automobile Parts. These Figures are to be Used in Conjunction with Tables II to VI Inclusive.

with gas than with oil, and the flame temperature is higher. Although the capital expenditure for oil storage tanks, pumps, strainers, and the like, are saved, nevertheless the price of the gas includes the charges on the central station and the distributing system, which operates as an offset expense.

The conditions that favor the use of electric fuel are not present in drop-forge furnaces. They are inherently wasteful, utilizing from $2\frac{1}{2}$ to 15 per cent of the available heat units, the chief loss being through the door opening. The use of bar stock imposes conditions upon the design, not favorable to fuel efficiency.

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The drop-forge furnace represents a compromise brought about by the necessity for rapid production, quality, and low cost. As a result of these antagonistic factors, the oil-fired forge furnace has given the most general satisfaction.

The average amount of steel heated is about 20 pounds per gallon of oil. On small work, requiring $\frac{1}{2}$ -inch square bars or less, as low as 10 pounds of steel per gallon of oil will be heated. This is not on account of inability to heat faster, but inability on the part of the drop forger to forge faster. On the other hand, with heavy forgings, crank shafts, for example, the weight of steel heated per gallon of oil may run over 50 pounds.

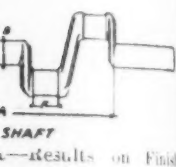
FURNACES

The drop-forge furnace is generally direct-fired, with rectangular hearth, roof arched from side walls, door opening in front, slag hole in rear. The brick work should be enclosed in a strong, well supported, well braced steel frame. The walls should contain not less than 9 inches of firebrick lining, and the space between the brick and the frame should be filled with insulating material. The arch skew-backs should be supported by the steel frame, and the thrust taken by tie rods across the top of the furnace. The door arches should be built of wedge brick, and not one piece lintels. The latter crack too easily. The brick should be grouted tightly.

Burners should be rigidly fastened to the steel frame in such manner that they cannot shift in position. The burner orifice should be in exact alignment with the center of the port brick. The burners should be placed just under the roof arch and offset with reference to each other if on opposite sides of the furnace. There should be a comparatively large combustion space above the hearth, in order that combustion may take place within the furnace, and that the flame may not impinge directly upon the bar stock.

The use of preheaters is desirable, but burner trouble may be experienced if the air is preheated above 500 degrees Fahr. The furnace should be provided with effective means for protecting the forger from the heat that issues through the door opening. The hearth should slope slightly toward the rear, in order that slag will flow toward the slag hole and not down the bar stock toward the forger.

Forgings made on the bar require a furnace comparatively



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narrow and deep. Forgings made from separate blanks, such as gears, require a furnace comparatively wide and shallow.

The forging temperature of low carbon steel is in the vicinity of 2100 degrees Fahr. The furnace is run considerably hotter, the softening point of the firebrick being the limiting point. It does not pay to force the furnace much beyond 2600 degrees Fahr. because the linings burn out too quickly. If the forger forges faster than the furnace heats, then the furnace is too small. A furnace properly operated will not only feed the forger, but will not require relining more often than every 1200 hours.

Only straight true brick should be used in the repair of a furnace. Contrary to the usual idea, it is not good policy to soak the brick in water before laying.

The bottom of the furnace is covered with quartz, crushed to the size of trap rock. This serves to elevate the steel somewhat above the hearth and permit heating from all sides, and it also allows the slag to trickle toward the slag hole between the interstices of the quartz without sticking to the steel.

EFFECT OF HEAT AND MECHANICAL WORK UPON STRUCTURE OF STEEL

In the accompanying diagram (Fig. 10), vertical distances represent temperature, and the width of each diagram represents the relative grain size.

First diagram from left illustrates the grain growth in steel cooling from the liquid state. Starting at point A, molten condition, the steel rapidly develops grains or crystals during the period of solidification, which increase in size less rapidly while the metal cools to the zone of critical temperature. The structure remains unchanged as regards grain size from this point to normal temperatures.

The second diagram from the left illustrates the effect of reheating upon the grain size. Whatever the size of the crystals in the cold metal before reheating, that size remains unchanged during the reheating until the critical range is reached. While heating through this zone there is a decided grain refinement. Increase in temperature beyond this zone causes the grains or crystals to augment in size.

The effect of forging or mechanical work upon the structure of the steel is shown in the two remaining diagrams. They indi-

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cate that the effect of forging and cooling is to break, crush, and knead the crystalline structure into grains of smaller size. When the forging is discontinued at any point above the critical range, the grain size immediately begins to increase in size as the metal cools until the piece enters into the range of critical temperature. This statement must be modified to the extent that the size of the piece of metal must be such that the rate of cooling is not fast

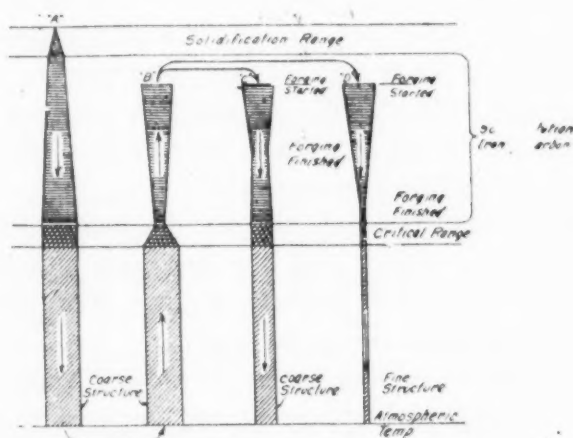


Fig. 10—Diagram Showing the Effect of Hot Working Upon the Structure of Steel.

enough to set the grain size. The maximum grain refinement is obtained when the forging work is continued until the metal has cooled to the critical range.

Hence, the temperature at which the forging work ceases, or the "finishing temperature," is the determining factor in grain refinement.

A forging finished at a comparatively high temperature may be more or less refined by normalizing. In fact, it is advisable to normalize drop forgings because the finishing temperature is more or less variable. Alloy steel and high carbon steel forgings are frequently annealed after normalizing to promote machinability. Forgings that have been overheated, and are coarse-grained, have a strong tendency to remain in that condition in spite of heat treatment. Burned, or severely overheated forgings should be rejected.

Drop forgings are generally of such small size that the rate of heating is not important for low carbon steel. In the higher carbon steels, particularly the tool steel ranges, and alloy steels, the metal should be heated slowly. Regardless of the grade of

steel, the rate of heating should permit complete penetration. When ordinary grades of steel are forged the furnace temperature is allowed to exceed the forging temperature, and run as high as 2600 degree Fahr. The forger loads the furnace in such relation to his rate of forging that each bar is withdrawn at the proper temperature. This temperature is about 2100 degrees Fahr.

High carbon steels should not be heated above 1950 degrees Fahr., and they should be finished in the vicinity of 1450 to 1500 degrees Fahr. So important is the finishing temperature that it may be necessary to lower the forging temperature; or in case of small pieces which cool rapidly, it may be necessary to resort to two heats. Under no circumstances should the limits of the temperature range mentioned be exceeded.

Nickel-chromium steels should not be heated above 2000 degrees Fahr. for good work; and the finishing temperature should be in the vicinity of 1500 degrees Fahr. The nickel-chromium series will not withstand abuse in heating.

The chromium-vanadium series is a very rugged series, and will withstand considerable abuse in heating and forging. In the lower carbon ranges they may be safely heated to 2100 degrees Fahr., provided the finishing temperature is in the vicinity of 1500 degrees Fahr.

High speed steels crumble when drop forged from high heats. The forging range is comparatively narrow, about 1750 degrees down to 1450 degrees Fahr.

The stainless steels have a narrow forging range. The steel must be heated to about 1950 degrees Fahr. and finished in the vicinity of 1550 degrees Fahr.

It is an unnecessary waste of fuel to run furnaces with a smoky flame, except in the case of high carbon steel. However, the oil should be so regulated that the flame is verging on the smoke. A hard, sharp flame is usually oxidizing.

A test of the furnace conditions is to toss a small piece of wood upon the hearth. If it bursts into flame, the atmosphere is oxidizing. By suitably regulating the oil or the air or both the furnace may be brought to a condition in which the piece of wood chars and cinders without flaming. This is an indication that a great excess of oxygen is not present, and that the furnace atmosphere is in the neutral, or nearly neutral, condition. This latter condition is the best condition for quality work.

HAMMERS

There are many types of forging machines. The manufacture of duplicate forgings in dies is most closely associated with board drop-hammers. In fact, the name "drop forging" was taken because "drop" hammers were originally used. The distinguishing feature of this type of hammer is that a board is utilized to lift the ram. In other countries, rope lifts, and leather strap lifts are frequently used, but in the United States no material has been found more satisfactory than sound, well seasoned, straight grained maple. The ratio of weight of base to weight of ram should not be less than 20 to 1 for hammers ranging over 1500 pounds; nor less than 15 to 1 for the lighter hammers. Hammers are rated according to the weight of the ram, and are built in sizes from 600 to 6000 pounds, the latter sizes usually having double rolls.

The hammer should be set up on a massive concrete base, with the ways for the ram perpendicular. The rolls must be absolutely true to size, and parallel. The operation of the eccentric bearings should be such that the movable roll maintains its axis parallel to the fixed roll in all positions.

Table VI

Hammer Ratings			Max. Height					Horse Power Required
Weight of Ram Lbs.	Weight of Base Lbs.	R. P. M.	Face of pulley Inches	Thickness of Board	Fall Ft. In.	Min. Fall Ft. In.		
400	7500	190	6	1 ¼	4 6	3 0		
500	7500	190	6	1 ¼	4 4	2 10		
600	9000	170	8	1 ¼	4 0	2 6		
800	12000	170	8	1 ¼	3 9	2 3		
1000	15000	130	10	1 ¼	4 6	2 6		
1200	18000	115	10	1 ¼	4 6	2 3		
1400	21000	115	10	1 ¼	4 6	2 3		
1600	24000	110	10	1 ¼	4 6	2 3		
1800	36000	105	12	1 ¼	4 0	2 3		
2000	40000	105	12	1 ¼	4 0	2 3		
2500	50000	100	16	1 ¼	5 0	2 6		
3000	60000	100	16	1 ¼	5 0	2 6		

The above data is not arbitrary, and may vary somewhat among the various hammer manufacturers.

Hammers are limited in the size of the work they will handle. The area of the forging determines to a great extent the size hammer to use. However, rating the hammers according to the size of bar stock, the following is a reasonable basis for the selection of hammer to employ.

Size of Steel		Weight of Hammer
$\frac{3}{8}$ -inch round to $\frac{3}{4}$ -inch square	-----	800 pounds
$\frac{3}{8}$ -inch round to $1\frac{1}{4}$ -inch square	.....	1000 pounds
1 -inch square to $1\frac{1}{4}$ -inch square	.....	1200 pounds
$1\frac{1}{4}$ -inch square to $2\frac{1}{2}$ -inch square	.....	1600 pounds
$1\frac{1}{4}$ -inch square to $3\frac{1}{2}$ -inch square	.....	2000 pounds
2 -inch square to 4 -inch square	.....	3000 pounds

The tendency is to use fewer blows and a heavier ram, even to the extent of using a very short stroke to speed up the hammer. This practice results in little attention being paid to the finishing temperature.

PRODUCTION PER HAMMER

The production to be expected upon a given forging is usually a judgment estimate based upon previous experience, of course. It is possible to grade hammers according to the projected area

Table VII
Hammer Production. (Forgings Per Hour)

Weight of Hammer	Projected Area Sq. In.	Thin Flat Forgings Flat Stock	Ordinary Forgings Sq. or Rd. Stock	Intricate Forgings
600	$2\frac{1}{2}$	440	350	200
	$3\frac{1}{2}$	350	300	175
800	$2\frac{1}{2}$	440	400	250
	$3\frac{1}{2}$	350	300	200
1000	$2\frac{1}{2}$	...	250	225
	$3\frac{1}{2}$	---	225	200
	$4\frac{1}{2}$	350	250	175
	6	250	175	150
1200	$4\frac{1}{2}$	300	250	175
	5	300	250	200
	$6\frac{1}{2}$	275	250	200
1600	5	250	225	200
	6	225	200	175
	9	200	175	150
2000	5	...	200	175
	6	...	180	160
	7	225	225	175
	9	225	225	150
2500	5	...	...	150
	6	...	...	150
	7	225	250	175
	9	200	200	140
	10	200	180	100
3000	13	145	150	75
	9	175	150	80
	11	160	100	80
	13	150	100	75

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- also the necessary die room machinery, and auxiliary equipment.

The relative values in these departments are assumed to be respectively, 5 per cent, 20 per cent, 5 per cent, 40 per cent, 20 per cent, 5 per cent, $2\frac{1}{2}$ per cent, and $2\frac{1}{2}$ per cent.

1. The fixed charges, consisting of all taxes, insurance, and water charges are assumed at \$8,900 per year, which is distributed among the various departments in proportion to the relative values.

2. The administrative expense, consisting of the office salaries and incidental expenses, are assumed at \$8500.

3. The depreciation is upon \$100,000, depreciated upon a basis of 20 years. Hence, \$5000 is apportioned among the various departments according to the values.

4. The supervision expense consists of the salaries of the foreman, distributed over the various manufacturing departments in proportion to a reasonable division of their time.

5. General non-productive labor includes the balance of the labor charges listed above. The apportionment among the various departments is in proportion to their activities, and is reasonably clear in the subjoined chart.

The remaining apportionment of expenses is self-explanatory.

Expenses	Office	Die Dept.	Steel Rack	Drop Shop	Press Room	Heat Treat	Pickle House	Shipping
	5%	20%	5%	40%	20%	5%	2½%	2½%
Fixed Charges	\$8900	\$445	\$1780	\$445	\$3560	\$1780	\$445	\$223
Administration	8420	8420	.....	.....	.....	.....	.....	.....
Depreciation	5000	250	1000	250	2000	1000	250	125
Supervision	4300	.....	900	150	1700	1100	150	200
Labor—General N-P	2000	100	100	100	1200	100	100	200
LABOR—SPECIAL N-P								
Repairs—Prod. Machinery	1000	.....	100	.....	650	150	50	.....
Repairs—Furnaces	600	.....	.....	570	575	.....	25	.....
Trucking	600	.....	50	100	100	100	50	100
Lubrication	100	.....	25	.....	50	25	.....	.....
Electrical	100	.....	25	.....	50	25	.....	.....
Belts and Shafting.....	200	.....	50	.....	100	50	.....	.....
Clerical and Shipping...	1800	.....	100	.....	300	100	.....	1300
Sanitation	100	25	25	.....	25	25	.....	.....
Blacksmith	1800	.....	.....	.....	.....	1800	.....	.....
Counting	600	.....	.....	.....	200	200	.....	200
Inspection	600	.....	.....	.....	200	200	.....	200
Fire Protection	100	25	.....	.....	25	25	10	5
MATERIAL								
Repairs—Prod. Machinery	400	.....	25	.....	300	75	.....	.....
Repairs—Furnaces	400	.....	.....	.....	375	.....	25	.....
Repairs—General	200	10	40	5	80	40	10	5
Trucking	50	.....	5	10	15	10	.....	10
Lubrication	75	.....	10	.....	50	15	.....	.....
Electrical	50	.....	5	.....	40	5	.....	.....
Belts and Shafting.....	400	.....	50	.....	300	50	.....	.....
Clerical	100	.....	10	.....	30	10	.....	50
Sanitation	25	5	5	.....	10	5	.....	.....
Blacksmith	100	.....	.....	.....	.....	100	.....	.....
Hammer Boards	600	.....	.....	.....	600	.....	.....	.....
Miscellaneous	1100	.....	100	.....	100	100	.....	800
Fire Protection	50	5	.....	.....	15	10	5	10
Light	150	50	50	.....	15	15	5	10
Heat	200	50	50	.....	10	50	25	15
Power	1500	.....	100	.....	1200	200	.....	.....
Fuel	6300	.....	.....	.....	6000	.....	300	.....
Totals	47920	9385	4605	1060	19875	5465	3350	1723

In actual practice the expense items to be distributed would be obtained from the books. The following data is also taken from the books:

Burden, as shown on the chart	\$ 47,920
Average steel purchases per annum	
1,700,000 lbs. @ .025/lb. delivered	42,500
Working hours per year, 2550	
Die steel purchased	1,500
Productive Pay-roll	
Drop Shop	8,197
Die Dept	6,100
Press Room	4,080
	<hr/>
	\$110,297
Profit 20%	22,000
	<hr/>
Gross business	\$132,297

From the above the following factors are obtained:

Administrative Factor	
\$ 9,385	or ----- 8.5%
110,297	
Die Department Overhead	
4,605	or ----- 75%
6,100	
Steel Handling Factor	
1,060	or ----- 0.001 per pound
1,700,000	
Steel Pickling and Shipping	
1,723 + 2,457	or ----- 0.0025 per pound
1,700,000	

Hammer Hour Rates

Continuous hammer production is out of the question, because dies must be set up, boards renewed, and the hammers repaired. In an ordinary job shop the hammers are engaged in production about 60 per cent of the time. A drop shop busy with long runs may average a productive efficiency of 70 per cent. 60 per cent however, is a more practical efficiency for a job shop.

Average hourly cost of operating the hammers:

\$19,875	or ----- \$13.00 per hour
2550 x .60	

The power required per hammer, the fuel consumed to heat the steel, and the repairs, all considerable factors in the burden, are roughly proportional to the weight of the ram. Distributing

the hourly cost over the hammers in accordance to the weight of the ram, the hourly rates for the various sizes of hammers are:

800-pound hammer	8/73rds of \$13.00 or 1.45 per hour
1000-pound hammer	10/73rds of 13.00 or 1.80 per hour
1500-pound hammer	15/73rds of 13.00 or 2.65 per hour
2000-pound hammer	20/73rds of 13.00 or 3.50 per hour
Trimmer Press Rates per hour	
Operating efficiency 80%	
5465.	
$\frac{5465.}{2550 \times .80 \times 4} =$	0.67 or 0.65 per hour

Set-up Charges

A reasonable charge to make for the setting of hammer dies is:

800-pound hammer	1 hour, forger and helper
1000-pound hammer	1¼ hour, forger and helper
1500-pound hammer	1½ hour, forger and helper
2000-pound hammer	2 hour, forger and two helpers

Press Department. An allowance of 1 hour for one man is sufficient.

An overhead charge should be added to cover the cost of tools and tackle used.

Furthermore, one set-up does not necessarily cover the requirements of the run. Dies wear, and must be removed for re-dressing; dies move, and must be reset. It is not excessive to allow one set-up charge for every 5000 forgings.

The Estimate (Per 100 Forgings)

Spindle Forging. Quantity, 20,000 pieces. Ordinary type. Rough weight, 1 pound. Size, 1 inch square. S. A. E. No. 1020. Projected area, 4 square inches. 1000-pound hammer. Forging production, 250 per hour, no helper. Cold trimmed, 300 per hour. Cost of dies, \$200, with an estimated life of 20,000 pieces. Maintenance expense assumed at \$80.

Material, 100 lbs. @ .025 per lb.	2.50	
Handling, 100 lbs. @ .001 per lb. ....		.10
Forge hammer, 1.70/250 x 100 .....		.68
Forge labor, .90/250 x 100 .....	.36	
Trim Press, .65/300 x 100 .....		.22
Labor, .50/300 x 100 .....	.17	
Pickling and shipping, 100 lbs. @ .0025 per lb. ....		.25
Set-up		
4 x 4.25 x 100 .....		.085
20,000		
	3.03	1.34
	1.34	
Factory Cost	4.37	

Administrative, 8.5%	.37
	<hr/>
Profit, 20%	4.74
	<hr/>
	5.69
Die Replacement Factor, $\frac{200 \times 100}{20,000}$	1.00
Die Maintenance Factor $\frac{80 \times 100}{20,000}$	.40
	<hr/>
	7.09
Selling Price	\$7.09 per 100

It will be observed that in this estimate no profit is charged upon the tools and dies. It will further be observed, then, when the 20,000 forgings are sold, there will have accumulated through the operation of the die replacement factor the sum of \$200, which pays for the dies.

There are minor omissions in the apportionment or budget sheet. For instance, an item for office supplies, should be entered under—Material, clerical. It would increase the administrative factor a fraction of a per cent.

At various time, a workman from the die sinking department performs repair work as a machinist. That is the explanation of the item "Labor from productive departments . . . \$1200." The productive pay roll should show a corresponding decrease.

The general principles involved in the hourly rate system are contained in this analysis.

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BEHAVIOR OF CARBON IN A HIGH CHROMIUM RUSTLESS IRON

BY M. A. GROSSMANN

Abstract

The carbon in a high chromium iron was found to be distributed non-uniformly after heat treatment. The carbon leads to the formation of separate austenitic areas, in equilibrium with regions of alpha iron. With rapid quenches from a high temperature, the metal is still soft, because most of it has remained as alpha iron; but the ductility of the metal has decreased greatly, because the carbon has led to the formation of well-distributed austenite areas, and these upon quenching become martensitic (and therefore hard) and so interfere with deformation. A series of photomicrographs are included which clearly show the structures which were observed in this investigation.

THE considerations presented here were developed in a study of a rustless iron of the high chromium type. An unusual behavior of the carbon presented several novel features of interest. The material was of approximately the following composition.

	Per Cent
Carbon	0.08
Chromium	17.5
Manganese	0.35
Silicon	0.75

It was known to be of the "non-hardening" type. That is to say, in the annealed condition, it had a Brinell hardness number of about 150, and no heat treatment was discovered which could raise its hardness much above 200. However, although the hardness did not vary greatly, there was a noticeable change in ductility in certain treatments. This change in ductility was an object of study and led to the observations recorded here.

When the annealed steel was heated above 1800 degrees Fahr. (980 degrees Cent.), it was found upon cooling to have decreased markedly in ductility. The following figures are typical of the steel before and after treatment, and illustrate the marked decrease in elongation and reduction of area in the tensile test

A paper presented before the Spring Sectional Meeting of the Society, Hartford Conn., May 20, 21, 1926. The author, M. A. Grossmann, member A. S. S. T., is metallurgist with the United Alloy Steel Corp., Canton, Ohio.

	Yield Point, lbs., sq. in.	Ultimate Strength, lbs., sq. in.	Per Cent Elongation	Per Cent Reduction of Area
(1) Annealed 30 minutes at 1425 degrees Fahr.	50,000	76,000	34.5	70.0
(2) Heated to 2000 degrees Fahr. and quenched in oil.	69,000	100,000	20.5	32.6

The mechanical properties remain substantially the same for different heating temperatures up to near 1800 degrees Fahr., and, once the new set of mechanical properties have been reached by quenching above 1800 degrees Fahr., then these new properties do not change greatly with further rise in quenching temperature.

Examination of the microstructure throws some light on the reasons for these phenomena. The structure of the bars in the "hot-rolled" condition is shown in Fig. 1. This is its structure immediately after rolling in the rolling mill, without further treatment. The micro-sections are cut longitudinally in the bars. They show certain areas elongated in the direction of rolling in which carbides are concentrated. When such a steel is heated to near 1800 degrees Fahr. and cooled more or less rapidly (water, oil or air), it acquires the structure shown in Fig. 2. It is seen that areas with sharp outlines have formed in the carbide regions. These will be shown later to be austenite and martensite. When the temperature is raised somewhat, it is seen (Fig. 3) that the formation of the austenite-martensite regions is still more definite. Above 1850 deg. Fahr. the austenite-martensite regions are unmistakable, being definitely identified at high powers. (Fig. 4).

Examination of the time-temperature curves of the steel, for transformation points, shows a critical point at about 1800 degrees Fahr. It was therefore to be expected that a recrystallization would be effected at this temperature. Careful examination of the structures obtained below and above 1800 degrees Fahr., however, seemed to indicate that there was no recrystallization, and that there was no change except the formation of austenite in the carbide regions. Repeated re-polishings and re-etchings failed to reveal any new grain boundaries in the grains A of Fig. 5, heated to 2100 degrees Fahr. and quenched in water. These grains A appeared to be the same as the grains A in the steel as hot-rolled, Fig. 1. It would appear, then, that the critical point noted at 1800 degrees Fahr. was due to the transformation from alpha iron to austenite in the carbide regions only, and did

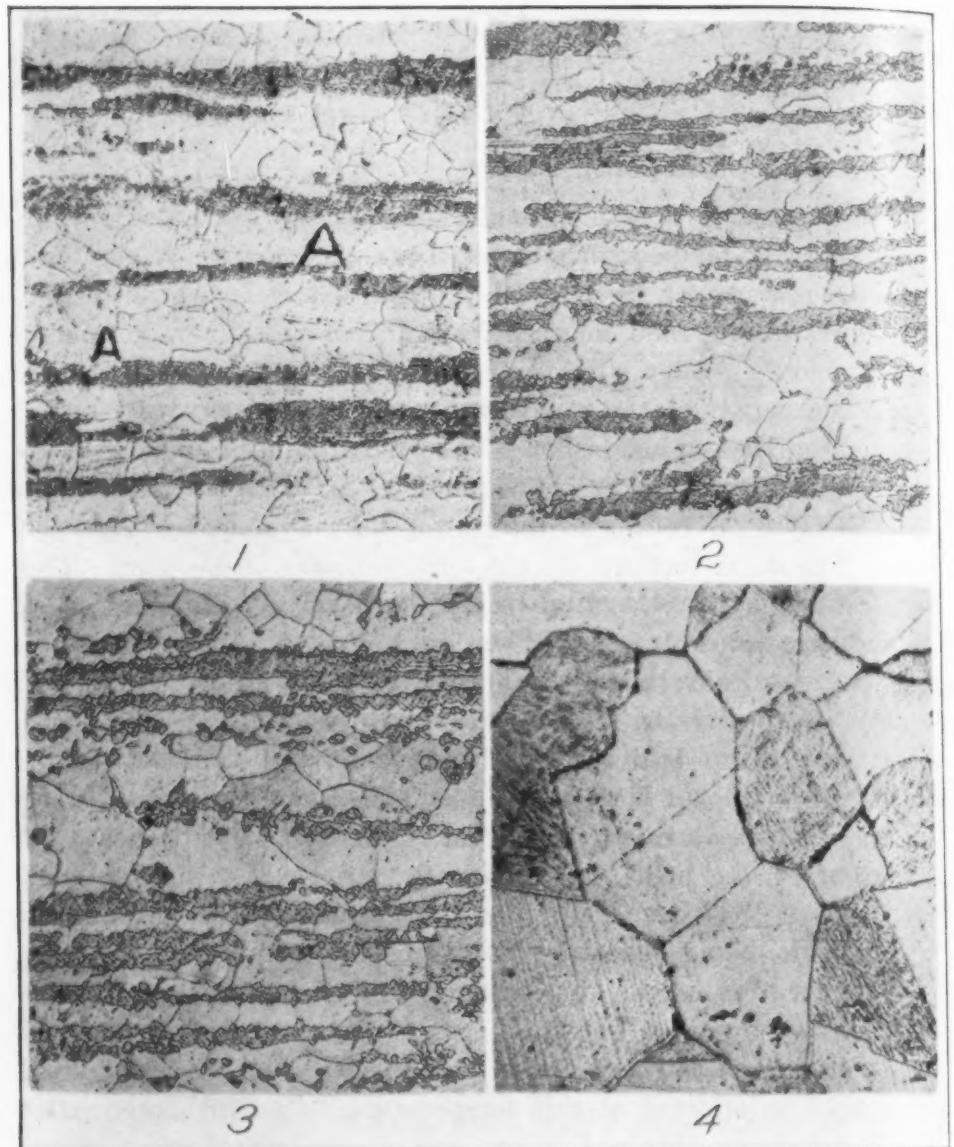


Fig. 1—Structure of High Chromium Rustless Iron as Hot Rolled. 100X. Fig. 2—Specimen Same as Fig. 1 after Quenching from 1830 degrees Fahr. Into Water. 100X. Fig. 3—Specimen Same as Fig. 1 When Quenched into Water from 1930 Degrees Fahr. 100X. Fig. 4—Specimen Same as Fig. 3 at Higher Magnification. 500X.

not involve all of the steel. A polished section of the steel of Fig. 5 was then compressed in a vise to develop slip bands. It was thought that if each of these grains were composed of a number of smaller grains which had escaped detection in the etching, then the changes in direction of the slip bands would indicate the grain boundaries. Instead, however, a novel condition was

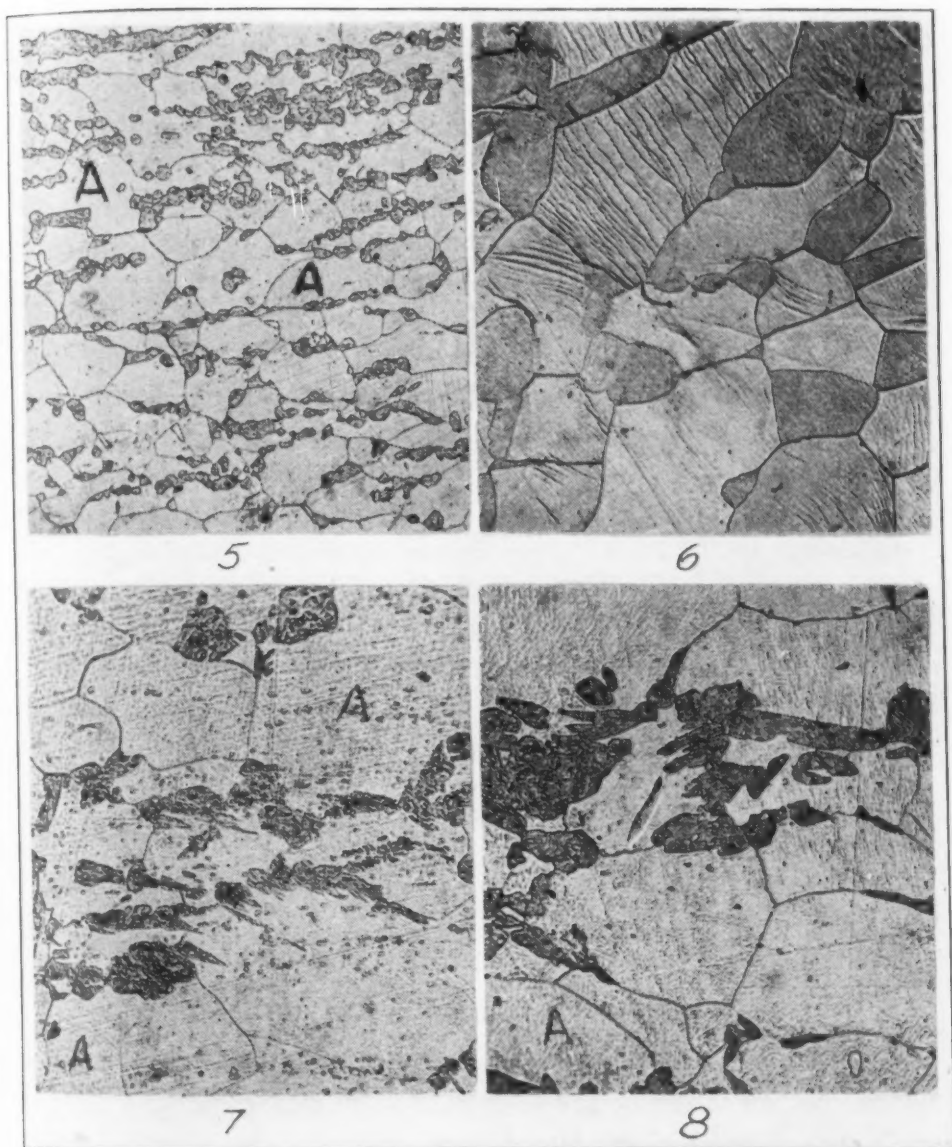


Fig. 5—Specimen same as Fig. 1 After Quenching from 2100 degrees Fahr. 100X. Fig. 6—Specimen Same as Fig. 5 After Compressing in a Vise to Develop Slip Bands. 250X. Fig. 7—Specimen Same as Fig. 1 after Quenching Into Water from 1715 Degrees Fahr. 250X. Fig. 8—Specimen Same as Fig 1 after Quenching into Water from 1830 degrees Fahr. 250X.

observed: the slip bands were indeed continuous in any one grain, but they were not straight. The irregular course of these slip bands is shown in Fig. 6. The significance of this is discussed below.

It was also observed that the slip bands stopped abruptly at the martensite grain boundaries and were absent in those grains,

as shown in Fig. 6. In the groups of alpha iron grains, there is merely a change in direction of the slip bands in passing from one grain to another. But when a grain of austenite-martensite is encountered, the slip bands stop abruptly: the martensite grains do not exhibit any ductility. This phenomenon undoubtedly explains the sudden loss of ductility upon quenching from above 1800 degrees Fahr. The heat treatment develops numerous areas of martensite which lack ductility, and which when present in the matrix of alpha iron grains interfere with slip and reduce the plasticity of the whole in the manner characteristic of slip interference. It is interesting to note that the nonductile areas are in this case much larger than the particles which are ordinarily discussed as interfering with slip.

A new series of test pieces was then examined after various heat treatments. Pieces were heated at successively higher temperatures, pieces being quenched from each of a series of temperatures, as follows. The pieces were all placed in the furnace together, and quenched one at a time as the furnace temperature increased. The time given is the total time taken to reach the temperature indicated, from the time the pieces were placed in the hot furnace.

Degrees Fahr.	Time in Minutes
1715	15
1830	20
1930	25
2035	31
2235	48
2320	58
2380	68

Examination of these steels showed that there was comparatively little change in the microstructure as the heating temperature rose, except that the grains between the austenite areas appeared to grow steadily in size as did also the austenite areas. Otherwise they seemed to retain their original nature. The quenched pieces were all magnetic, which showed that they consisted for the most part of alpha iron. The grain growth is shown in Figs. 7 to 13.

Since there were no evidences of recrystallization, it was obvious that the alpha iron regions had remained as such, even upon heating up to high temperatures. The nature of this behavior has been shown for the carbonless iron-chromium alloys

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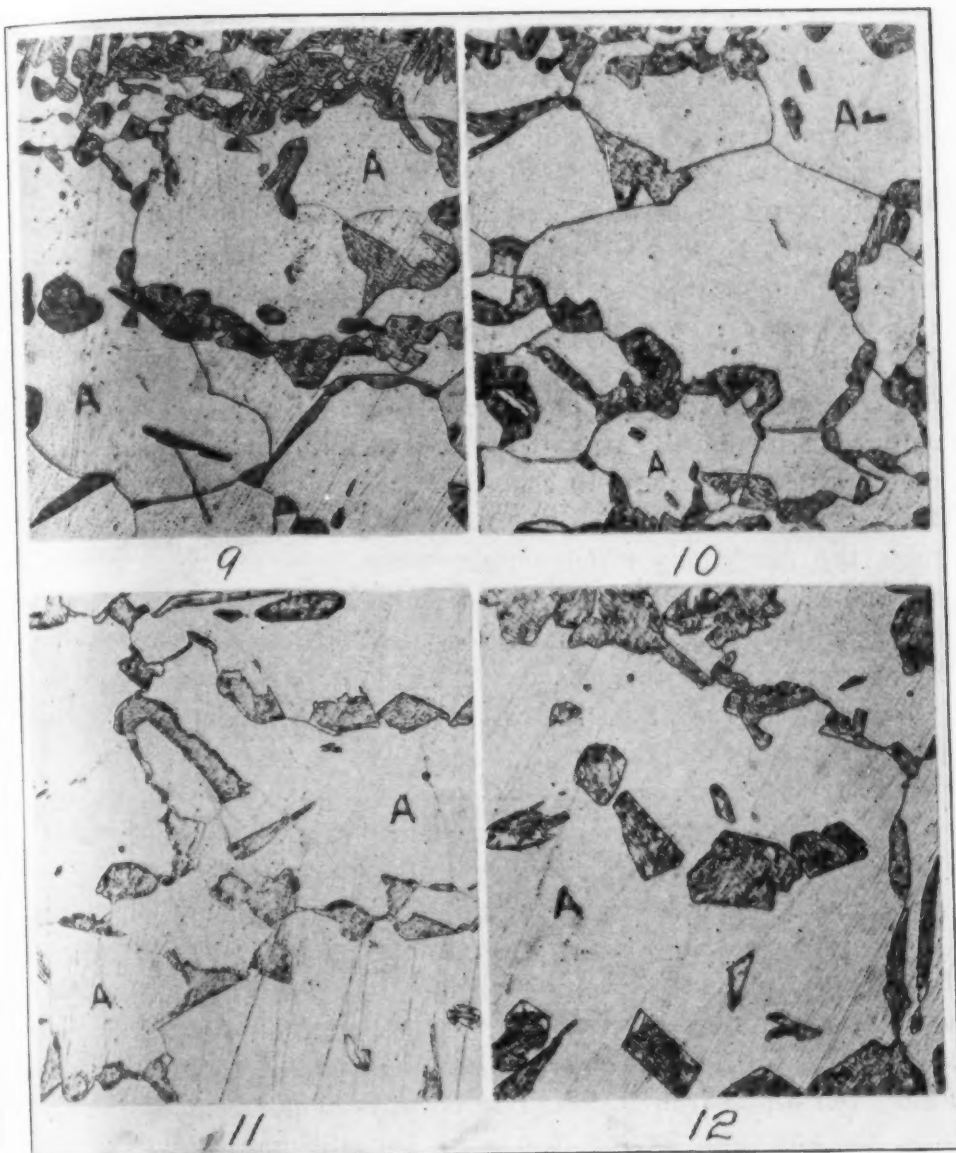


Fig. 9—Specimen Same as Fig. 1 after Quenching into Water from 1930 degrees Fahr. 250X. Fig. 10—Specimen Same as Fig. 1 after Quenching into Water from 2035 degrees Fahr. 250X. Fig. 11—Specimen Same as Fig. 1 after Quenching into Water from 2235 degrees Fahr. 250X. Fig. 12—Specimen Same as Fig. 1 after Quenching into Water from 2320 degrees Fahr. 250X.

by Bain¹, who showed in his fundamental research that beyond a certain percentage of chromium the alpha-gamma transformation does not appear. There is a "loop" in the iron-chromium diagram, within which gamma iron may be formed, but beyond which alpha iron forms a continuous series with delta iron with

¹E. C. Bain, "The Nature of Alloys of Iron and Chromium," TRANSACTIONS, American Society for Steel Treating, Vol. 9, January, 1926, page 9.

which it is of course identical. In the present case, then, we have at the high temperatures a large number of grains of alpha iron, in contact with (and nearly in equilibrium with) a number of grains of austenite. The low carbon steels with whose microstructures we have been familiar have always exhibited upon prolonged heating a condition in which the austenite slowly absorbs the ferrite. In the present case this does not take place, because the alpha iron possesses a stability at least as great as that of the austenite. The alpha iron, indeed, appears to exhibit a stability even greater than that of the austenite. There is at least a co-existence at high temperatures of grains of alpha iron with grains of austenite. It will be observed in the series of photomicrographs Figs. 7 to 13 that there is a gradual increase in the size of the grains of alpha iron, A. These photomicrographs show the conditions which obtain when the heating is of short duration. In order to examine conditions approaching equilibrium, similar samples were heated at 1900 and at 2100 degrees Fahr. respectively, for periods of six hours, the specimens being then quenched in water to preserve the structures. Representative structures are shown in Figs. 14 and 15. A general impression is gained from Figs. 7 to 13 that the grains of alpha iron grow at the expense of the austenite areas. Grain size measurements were made on a number of representative photomicrographs of the specimens shown in Figs. 14 and 15. The measurements show that after heating for six hours at 1900 degrees Fahr. the alpha iron occupies about 65 per cent of the volume, with austenite, of course, as the remaining 35 per cent. When the temperature of the 6-hour heating is raised to 2100 degrees Fahr., the alpha iron is found to occupy 75 per cent of the volume, the austenite having decreased from 35 per cent to 25 per cent. This indicates some encroachment of the alpha iron into the austenite regions.

At the same time the grain size measurements throw some light on the high temperature equilibrium between alpha iron and austenite. At 1900 degrees Fahr. the average size of the grains of alpha iron was found to be about $5100\mu^2$ ($\mu = 0.001$ millimeters; $\mu^2 = 10^{-6}$ square millimeters). On raising the temperature to 2100 degrees Fahr., the grain size rose to $11,100\mu^2$. On the other hand, the average size of the austenite grains rose from about

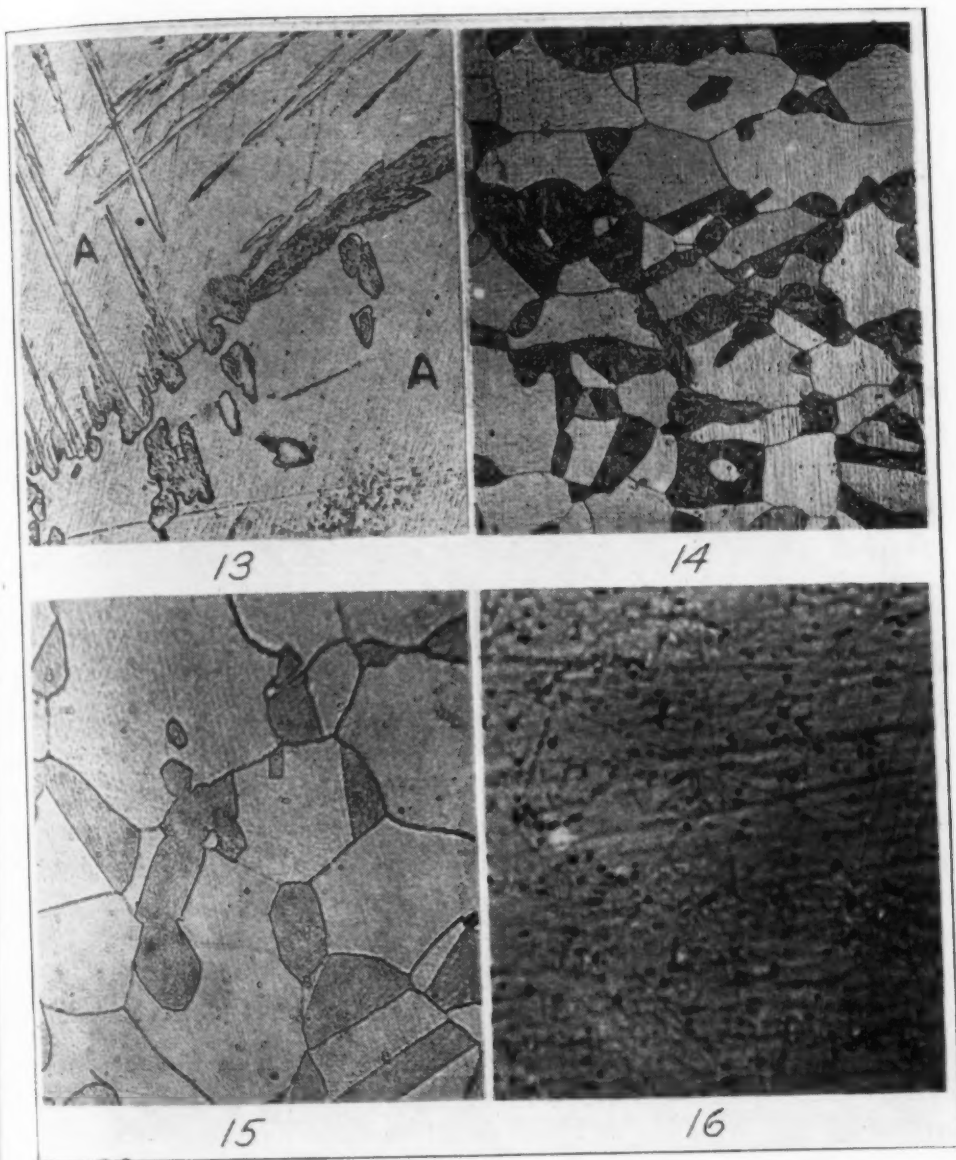


Fig. 13—Specimen Same as Fig. 1 after Quenching into Water from 2380 degrees Fahr. 250X. Fig. 14—Specimen Same as Fig. 1 after Heating for Six Hours at 1900 degrees Fahr. and Quenched into Water. 250X. Fig. 15—Specimen Same as Fig. 1 after Heating for Six Hours at 2100 degrees Fahr. Quenched in Water. 250X. Fig. 16—Specimen Same as Fig. 6 Showing Precipitated Carbides Revealed Under High Power. 1500X.

2600 μ^2 to about 3900 μ^2 . These grain size phenomena are a good index of the nature of the equilibrium between the alpha iron and the austenite at high temperatures. On the average, the stability or orienting power of the alpha iron at high temperatures is somewhat greater than that of the austenite, as evidenced by the fact that the total proportion of alpha iron increases from

65 to 75 per cent at the expense of the austenite. Nevertheless, in individual cases, the stability or orienting power of the grains of austenite may be greater than that of the contiguous grains of alpha iron, since the austenite grains have grown in size, and the growth has only partially been an absorption of neighboring austenite areas. The fact that the austenite grains show a tendency to become equi-axed and at the same time increase in size shows that there must have been some grain growth into adjacent grains of alpha iron.

The latter phenomenon (absorption of alpha iron by austenite) is a common one in low carbon steels. The other reaction, however,—the growth of alpha iron into austenite with rise in temperature—is a novel one. At the planes of contact between the grains, the alpha iron with its greater orienting power causes the iron atoms in the austenite to re-orient themselves progressively, and become part of the grains of alpha iron.

The carbon which had been in solution in the austenite would have two possible courses to follow. It could either combine with metal and form carbide, which would precipitate in the alpha iron (in which it is of course insoluble) or it could migrate into the adjacent austenitic area in which it would be soluble. There is some evidence that both processes take place, with the former predominating,—that is, most of the carbon of the re-oriented austenite is precipitated *in situ* as carbide particles when the austenite changes to alpha iron. Under this theory, there would be distributed through the alpha iron a large number of small particles of carbide. This would account satisfactorily for the irregular course of the slip bands, as illustrated in Fig. 6 and referred to above. Subsequent examination at higher powers gave good indications of the presence of these small carbide particles. See Fig. 16 at a magnification of 1500 diameters.

Further evidence was developed that the particles which interfered with the straightness of the slip bands were carbide particles. For it is conceivable that a large number of minute nonmetallic inclusions could have been present and so have caused the same effect. Evidence against the latter explanation appeared in the following experiment. A piece of the same steel was carburized by heating in powdered graphite for a number of hours at 1900 degrees Fahr. The carburization introduced enough car-

bon in certain areas to cause the austenite to be completely retained upon quenching—that is, there was enough carbon to avoid formation of martensite. When such a structure was polished and then compressed, slip bands and twins were formed, as in Fig. 17. It will be noted that the slip bands are perfectly straight,



Fig. 17—Specimen Same as Fig. 16 After Carburizing for a number of Hours at 1900 degrees Fahr. Using Powdered Graphite. The Specimen is Polished and then Compressed Developing Slip Bands and Twins. It will be noted that the Slip Bands are Straight as in a Homogeneous Material.

as in a homogeneous material. Thus the addition of more carbon to the original carbide particles made a homogeneous material— austenite. Had the interfering particles, which caused the slip bands in the alpha iron to be irregular, been nonmetallic inclusions, they would still have been present as such in the austenite and would have caused the slip bands in the austenite to be irregular also. It cannot be regarded as proven that the irregularity of the slip bands is due entirely to the carbide particles, but the latter can be considered as contributing to that irregularity. They would cause the slip bands to curve around them in the same way that the slip bands curve around martensite areas, as illustrated at several points in Fig. 6.

SUMMARY

1. In examining the microstructure of a high-chromium rustless iron, a novel equilibrium was observed between alpha iron

and austenite at high temperatures. Areas in which carbides were concentrated would, upon heating, form austenite, but no amount of further heating would cause any absorption of alpha iron by the austenite. The austenitic areas result, upon cooling, in an austenite-martensite structure.

2. The martensitic areas exist as hard regions in a plastic matrix of alpha iron. This reduces materially the ductility of the whole, although not greatly increasing its Brinell hardness.

3. The existence of numerous minute carbide particles, embedded in the alpha iron, was deduced from the irregularity of slip bands and from a behavior upon carburizing.

4. The carbide particles are in part the result of precipitation of carbide, when alpha iron grains encroach into austenitic areas at high temperatures.

ACKNOWLEDGMENT

The author wishes to express his indebtedness to J. D. Gat for preparation of photomicrographs and assistance in preparing specimens.

HEAT TREATMENT OF DIE BLOCKS

BY A. J. PORTER, JR.

Abstract

This paper outlines briefly the development of the die block to meet the demands placed upon it through the rapid growth of the drop forging industry.

It explains the various grades of die blocks used today and in general the type of forging to be made in each grade. In addition, suggestions as to a commercially proper method of hardening are given.

Some space is devoted to explaining ways in which die blocks are mistreated, which mistreatment causes breakage.

In conclusion arguments are advanced for the heat treated die block.

IN leading up to the central thought of this paper it is interesting to pause for a moment and briefly consider the development of the drop forging industry and together with it the development of the die block which naturally had to be perfected to meet the demands placed upon it.

Roughly speaking the drop forging industry is about seventy-five years old. In comparison with some of the other trades it is a mere youngster. By virtue of its youth and prospects of its further growth it is, however, a very aggressive, wide awake youngster. The first drop forging to our knowledge was done in connection with the carriage hardware business and most of it in the New England section of the country. Later the manufacture of the bicycle and bicycle tools required parts that could be drop forged and to meet the demand the industry expanded somewhat.

However the trade received its big impetus with the advent of the automobile and has expanded and grown along with that industry until now it is practically a part of it. Of course there are many other lines of drop forging other than automobile parts, such as wrenches, tools of all kinds, railway parts, etc., but today, to the outsider and to the insider, so to speak, drop forging is largely a part of the automobile business.

The point to be brought out is that drop forging which em-

A paper presented before the Spring Sectional Meeting of the Society, at Hartford, Conn., May 20-21, 1926. The author, A. J. Porter, Jr., member of the Society, is sales manager for the Heppenstall Forge Company, Bridgeport, Conn.

braces die sinking, die hardening and the actual forging has developed greatly in a short period of time. The diversification of product is wide both in utility and size. For instance, we now have products ranging from a scissor forging, weighing only a few ounces, to the rear axle housing of an automobile truck, weighing several hundred pounds.

Now, what we have been leading up to is the fact that along with this tremendous growth the die block had to keep pace.

During the carriage hardware and bicycle phases the original high carbon, crucible tool steel, water hardening block was used and did its work well. But, when forging of automobile parts commenced and these gradually kept increasing in size it was found that a great percentage of blocks broke in hardening. Investigation proved that it was commercially impossible to harden large size tool steel, water hardening blocks successfully. Roughly it was found that the strain set up by quenching the large mass of high carbon steel was too great. This condition came about approximately twenty-five years ago. To combat and overcome it a medium carbon, straight carbon block was placed at the disposal of the drop forger. This type of die block was immediately successful and answered the demand for the time being. However, shapes forged were rapidly becoming more intricate, necessitating dies with intricate impressions and projections. Secondly, more production per sinking was required and faster production was a vital demand. To meet and surmount these problems the drop forger turned to the alloy oil hardening blocks.

But this was not the end. It was found to be possible to forge extremely large parts. These forgings were too large to be made in dies which could be hardened after sinking. This condition meant that dies, which had been hardened previous to being sunk, must be used. These dies were left hard enough to withstand wear in forging and yet soft enough to be cut by the die sinker. This marked the advent of the heat treated block which has had a remarkable development in quality and popularity in the last few years, especially throughout the west.

In passing it is well to consider briefly each of the grades outlined and state roughly the type of forging for which they can be used, together with their respective merits.

The tool steel block, either crucible, electric or open-hearth,

is intended primarily for small dies where extremely high hardness is required. It is essentially a water hardening steel.

The medium carbon steel block can be used for a general line of drop forgings. It is also a water hardening block. This is an extremely versatile grade of steel insofar as practical use is concerned and it is difficult to say just what type of forging should or should not be made in it. Roughly speaking it can be used for forging any small or medium size parts with excellent results.

The alloy oil-hardened block is rapidly growing in popularity. It is a block adapted for either the simplest or the most intricate impression and comes as near as is commercially possible to overcoming hardening difficulties. It lowers materially the risk of breakage in hardening. With this type of steel the warping and distortion in hardening are reduced to a minimum. In the actual forging, if tempered properly, it relieves the bugaboo of checking entirely. Drop forgers are using this block where especially long runs are desired on small or medium forgings.

Roughly there are two grades of heat treated blocks. The lower grade is used by the drop forger generally for extremely large forgings. The higher grade for medium and larger sized pieces.

MANUFACTURE OF DIE BLOCKS

To the average layman a die block as furnished to the drop forger is merely a block of steel. He has little conception of the vast amount of thought and skill both in a metallurgical and an engineering sense which are necessary to produce the ultimate product.

Extreme care in the selection of the proper composition, in melting and casting the ingot, in forging the blooms, in chipping for surface defects and later in forging and upsetting of the block are necessary. Following these operations the annealing and heat treating must be carefully planned and perfectly executed to insure a product which will withstand the extreme service of continual hammering, when the block is finally put into service in the drop forge plant. The reason for outlining so briefly the care taken in the manufacture of the die block is to stress the fact that the die block manufacturers realize the extreme service to which their product will eventually be subjected and for that reason are making it as perfect as possible.

The following is an outline of a few personal opinions as to

how die blocks are broken before, during, and after hardening. Following that will be an outline, a method of hardening which, if adhered to carefully, systematically and intelligently, will aid materially in reducing loss due to die breakage.

What can be done to dies before hardening to cause breakage? The drop forger spends an average of three hundred dollars to sink an impression in a pair of dies. This work is done in a high class die room by a skillful group of workers and yet many times carelessness in this department, in workmanship and design, leaves flaws which are instrumental in causing the block to break, checking the impression or otherwise destroying its usefulness. An outline of a few of these matters will be interesting.

First, no sharp corners should be left in an impression unless absolutely necessary. It is especially important to watch this point at the bottom of raised portions of the die. A radius strengthens for the actual forging and also lowers the risk of lifting off the raised portion when hardening.

Next, the maximum draft possible should be allowed. This of course lowers the possibility of the forging sticking and thus checking the impressions. As large a radius as possible should be left at the bottom of deep or reasonably deep impressions. This also aids in preventing the forging from sticking and assists the metal to flow readily under the hammer blows.

Another point is in connection with locked die impressions. The degree on both sides of the lock should be made as nearly equal as the design will permit. Carefulness in regard to this point will permit and aid, to a very great extent, in the flow of the metal during forging.

Going a little further it may be well to suggest that sufficiently large blocks be used. Many times deep impressions are placed too near the edge of a block. With this condition there is not enough body of metal between the impression and the edge of the block to insure strength and the eventual result is a broken block. It is always a wise precaution to buy a block large enough to avoid this possibility. Blocks should not be used after they have been cut down too thin. In many instances this is poor economy due to the block breaking because of insufficient body to provide the necessary strength.

A final caution in regard to die sinking is to see that all

scraping on deep impressions is done up and down and not horizontally. With this method of scraping if there are any rough spots left in the side of the impression they will be vertical and will assist the metal flow under the hammer. If the scraping is done horizontally the rough spots are liable to run in that direction and retard the flow in forging. These are only a few of the many points to be watched. Every die sinker is familiar with them and with most men they are avoided subconsciously.

BREAKAGE DURING HARDENING

How are blocks broken during the actual hardening operation? For argument, let us forget all that has been previously said about die sinking faults and consider that that operation has been perfect as it most usually is. We will proceed to the hardening room with a first class block of die steel perfectly sunk. In this department the block can be spoiled in a few moments. The first fault in heat treating is that of placing a cold block in a furnace which is too hot. A block should never be charged in a furnace which is over 600 degrees Fahr.

Seventy-five per cent of hardening faults lie in improper heating previous to the quench. Blocks are heated too quickly and the center is never brought up to the same heat as the outside. Sufficient time is not given to thoroughly heat the steel. A safe amount of time to allow is one hour per inch of thickness. The result of such quick heating is a cracked or broken block for the unevenness of the heating is sure to set up strains which cannot be controlled. Briefly, thorough temperature control and a uniformly heated block are the secrets of successful hardening.

Let us go one step further and take for granted that we have a correctly heated block. What can we now do to cause breakage? We can, in hardening, cool the block too little or too much and in this way get into trouble. An excellent practical method of determining when a die block has been cooled sufficiently is to place the fingers into the impression when the block is still immersed and if the fingers can be left there for a few seconds the block is sufficiently cooled to be withdrawn from the bath.

The final link in the hardening operation is the draw or temper. After being taken from the bath the block should be drawn shank down on a hot plate. It is essential that this drawing start immediately after the quench as the strain set up in the block is ter-

rific and must be relieved quickly. Sufficient heat should be forced into the block to relieve all strains and to draw it back to the proper hardness for the work it must do.

Finally, how are blocks broken after hardening? Along this line the first caution will be to see that dies are stored in a room which is kept at a fairly uniform temperature, winter and summer. This destroys the possibility of the blocks becoming chilled, in which condition they are liable to break when placed in the hammer and struck. With this thought in mind it is well to make note that dies should be warmed in the morning or whenever the hammer is started after laying idle. This is especially necessary in the winter. When a new pair of dies are started in the hammer it is extremely good practice to use them cautiously until the first few hundred forgings have been made. By this time the blocks will have been well smoothed up and will be ready for steady hard forging. This can be accomplished by heating the forging bars hotter than ordinarily necessary and taking a few more extra and lighter blows to make the first hundred or two forgings. If dies stick slightly they should be dressed up until this fault has been eliminated. Care along these lines is more than repaid in the production per sinking derived from the blocks.

Furthermore it is well to avoid the excessive use of oil in the impressions when the forgings are sticking. This sticking can be eliminated by spending a little time in smoothing up the impression. The time spent in this necessary dressing is refunded many times in the vastly increased production obtained from the dies.

It can be said quite truthfully that the drop forgerman who uses an excessive amount of oil is a lazy workman, as he is depending on the explosion, caused by the oil in the impression, to force the forging up and out of the dies and thus save him from lifting it out. The use of too much oil will, in many instances, eventually break a block.

A final suggestion as to how die blocks are broken after hardening lies in a reference to good or bad bearings between die block and shoe or sow block. It is well to exercise great care in making sure that dies have a good even bearing all around. Many dies are broken because this part is not watched and the fault corrected.

The alloy heat treated shoe forging which is now rapidly gaining in popularity has gone a long way to overcome this fault. Before the introduction of this type of shoe most any kind of steel was used for shoe forgings. Usually a piece of medium carbon or soft steel was used. There was no hardness inherent in these shoes and under the continual hammering the die block bedded itself in the shoe block. When it came time to change dies it was necessary to replane the shoe. If this were not done, and if the new die placed in the shoe was of a different size than its predecessor, it would not have a uniform bearing and in many cases no bearing at all. The result was a broken die. The heat treated shoe offers vastly more resistance to the die bedding and thus relieves the necessity of frequent replaning and the possibility of die breakage due to incorrect bearings. We have now outlined briefly a few of the ways in which blocks are treated before, during and after hardening so as to cause them to either break or give extremely unsatisfactory service.

Let us now pass on to our next thought and establish some recommendations as to a standard hardening method. These recommendations, together with the correction of faults as previously outlined, will form the author's proposal for a commercially correct hardening procedure.

When hardening drop forge die blocks one thing should always be kept in mind. This is that hardness is not the only essential. The draw or tempering is just as important, if not more so. Blocks left too hard will quickly be sources of trouble while a block which is drawn back will be placed in a condition to give satisfactory service.

Let us now consider for a moment what is today considered the proper method for hardening, first water and then oil hardened blocks.

Water Hardened Dies. The block should be heated face up in a furnace large enough to insure a uniform heat throughout the block. It is well to cover the face of the die to prevent undue sealing if there is much oxidation in the furnace. If the furnace used provides a good reducing flame no covering is necessary. We have previously cautioned regarding the matter of taking sufficient time in heating to insure a thoroughly and uniformly heated die. It therefore will not be necessary to repeat anything

with reference to this phase. Correct temperature control is something entirely dependent on the furnace and the operator.

Let us now assume that we have a correctly heated die block and proceed to the quenching operation.

The block should be quenched face down over a geyser of water. The geyser should have a sufficient force of water to insure that the heat from the center of the block will be carried away at approximately the same rate as the corners are cooled. The block should be immersed to a point about one inch below the depth of the impression. While the face is cooling the shank should be cooled in a manner which will prevent distortion of the face. It is a difficult matter to make any recommendation for a method for cooling the shank. This operation depends mainly on the shape of the block and yet every individual hardener has his own idea as to the proper way to treat the shank. As stated before the block should be cooled until the fingers can be placed in the impression while still immersed.

Oil Hardened Dies. The block should be handled in a similar way to the water hardened die until it enters the oil. At the start of the quench the die should be totally immersed and left beneath the oil until it is cooled sufficiently as not to flash the oil. Then it should be raised and left with the shank protruding from the bath. It is not necessary to cool the shank further as the first immersion has brought it low enough to prevent distortion of the face. It is important that the oil bath be equipped with a geyser of good force and a cooling system which will insure against the oil becoming too hot.

As was previously stated the draw is as important as the quench and the author again wishes to stress that point. All blocks should be brought quickly to the draw after coming from the quenching medium. The most practical method known today for drawing drop forge die blocks is on the hot plate. The die should be placed shank down on the plate and the heat forced into it quickly at the start. To insure this it is well to have the hot plate made in two sections so that the sections may be pulled apart and the shank dropped down over the flame from the burners. As the heat commences to come through the die it can be raised and the plates pushed together.

The first purpose in drawing is to relieve all strains set up

in hardening. After that is accomplished all attention should be devoted to intelligently draw the block to a hardness consistent with the type of impression and the size of the block.

One paramount caution should always be borne in mind and that is to draw the block back to a slightly higher degree than it shall be heated in the actual forging operation. This will go a long way to overcome the failure of the die through the development of checks. This warning can be summed up in one sentence, namely, draw dies back farther than the forging will draw, since if the forging is allowed to heat the die to a higher degree than the draw temperature the die blocks are badly checked. In other words, draw the dies in the hardening room and not in the drop shop.

Before closing the author would like to present a few thoughts regarding heat treated die blocks, that is, die blocks bought by the drop forger already heat treated and ready for use after sinking. This is done in a purely disinterested manner, and with the feeling that if I failed to call a few important points to your attention I would be neglecting my subject. In this connection please allow me to make a rather broad statement, namely, that on the average die block hardness is not essential for long wear. Toughness and a comparatively soft block are more desirable. Many drop forgers in the middle west are using die blocks which are furnished to them heat treated and to which they do no further hardening after sinking.

First, they can get good production even on small forgings from heat treated die blocks. Second, on average and large size forgings, no matter how hard the dies, if they themselves have done the hardening, the heat of the forging will draw the block back to approximately the same scleroscopic hardness at which they could purchase and sink heat treated blocks. In other words, drop forgers can procure and sink a block already hardened which is sufficiently hard to withstand wear and yet soft enough to sink.

They realize that these blocks take about 25 per cent longer to sink but after sinking they are able to put the dies into the hammer immediately. In so doing they avoid any possibility of breakage and distortion in hardening. Furthermore, when the block is worn down they do not find it necessary to anneal and

cut away the old impression entirely before resinking and then rehardening. They merely dress down the existing impression without annealing and return the dies to the hammer shop.

They have found, therefore, that for the average and larger sized forgings, the heat treated block is more desirable both from a practical and an economical standpoint.

The point that we have been leading up to is that, in the author's opinion, the hardening of die blocks in drop shops will be to a very great extent a thing of the past within a short time. It is rather a bold statement to make and yet I would predict that eventually die blocks will not be given the severe treatments to which they are at present subjected. In place of this we will be using blocks made from steels, the analysis and natural hardness of which alone will give the necessary wear-resisting qualities to fit them for drop forging purposes.

Educational Section

These Articles Have Been Selected Primarily For Their Educational
And Informational Character As Distinguished From
Reports Of Investigations And Research

THE CONSTITUTION OF STEEL AND CAST IRON— PART IV

By F. T. SISCO

Abstract

The present installment, the fourth of the series, discusses the critical or transformation points of low and medium carbon steels. The constitution of these steels and their behavior are described according to the Iron-Carbon diagram. Numerous photomicrographs of typical structures are included.

STEEL and cast iron are binary alloys of the metal iron and the nonmetal carbon. At high temperatures, 2730 degrees Fahr. (1300 degrees Cent.) and above, iron and carbon react readily to form the definite chemical compound iron carbide, Fe_3C .

Iron carbide is partially soluble in iron in the solid state. The result of this limited solubility is that the alloys of iron and iron carbide consist of a solid solution of iron carbide in iron and a eutectic alloy of this solid solution and iron carbide. In the steel series we are concerned chiefly with the solid solution of iron carbide in iron, in cast irons we will deal with this solid solution and also with the eutectic.

Iron carbide is made up of 1 part carbon and 15 parts of iron. The atomic weight of carbon is 12 and of iron is approximately 56. Then the formula weight of Fe_3C is $3 \times 56 + 12$ or 180. The percentage of carbon is found by dividing the atomic weight of carbon or 12 by the formula-weight of iron carbide, or 180, which gives 0.0667. This multiplied by 100 gives 6.67 per cent, or 1 part carbon to 15 parts of iron.

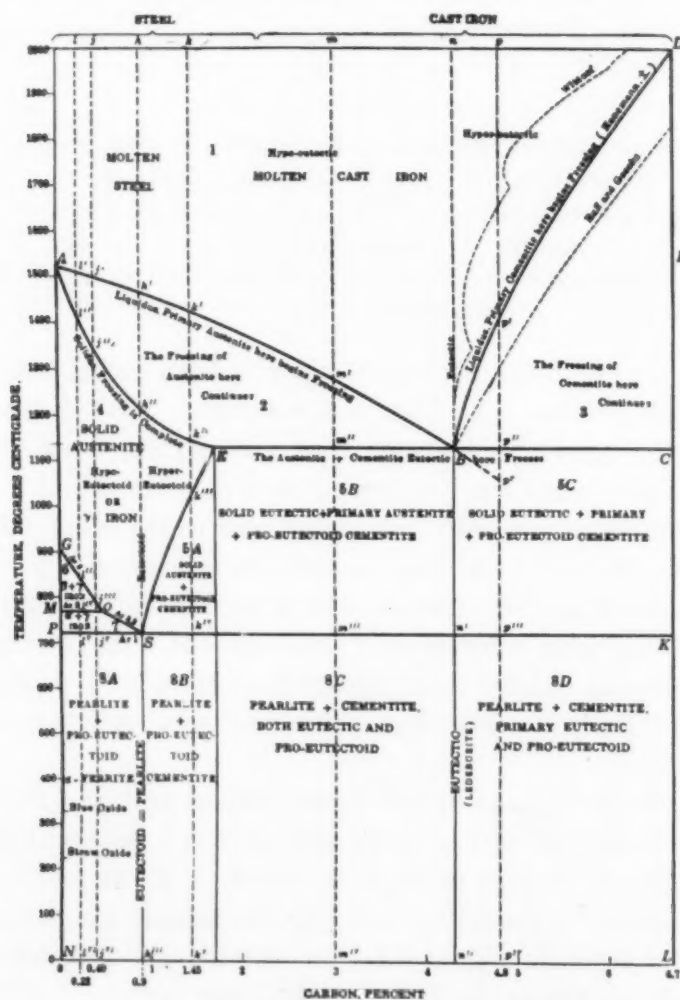
From these calculations it is readily seen that when an iron-carbon alloy contains 6.67 per cent carbon it will, theoretically, consist wholly of the chemical compound Fe_3C ; no uncombined

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iron will be present. Hence the iron-carbon series includes alloys of iron and carbon containing from 00 to 6.67 per cent⁵² carbon equivalent to 00 to 100 per cent iron carbide.

GENERAL FEATURES OF THE IRON CARBON DIAGRAM

Fig. 22, after Howe, shows the complete iron-carbon diagram. This is reproduced here so that we may observe its general features



The metastable or cementite-austenite carbon-iron diagram.

Fig. 22—The Complete Iron-Carbon Equilibrium Diagram (Howe).

even before discussing any of the alloys which it represents.

The complete diagram is the result of thousands of cooling

⁵²When we take up the cast iron series we will see that, practically, the maximum solubility of carbon is about 5 per cent. Theoretically the maximum is 6.67 per cent, or 100 per cent iron carbide, consequently the iron-carbon diagram is constructed on this basis.

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curves made by a great many investigators on very pure alloys of iron and carbon. The location and the character of the constitutional changes in the alloys containing up to about 5 per cent carbon have been fixed definitely. The exact position of the line BD for alloys containing more than 5 per cent carbon is still uncertain. Howe has indicated three lines on his diagram (Fig. 22).

The line ABD is the liquidus, above which all of the alloys of iron and carbon are wholly molten. The line AEBC is the solidus, below which the alloys are wholly solid. In the temperature range falling within the area AEB and BDC the alloys are partly solid and partly molten. This is the mushy stage with which we became familiar when we discussed the alloys of cadmium-bismuth. If we compare Fig. 22 with the diagram for the cadmium-bismuth alloys⁵³, it will be noted that the iron-carbon alloys solidify in much the same way as the cadmium-bismuth alloys. It is only below the solidus line that noticeable differences occur. The cadmium-bismuth alloys have no lines occurring below the solidus, the iron-carbon diagram on the contrary has lines GO, MO, OS, PS, SE, and SK. These lines denote various constitutional changes taking place in the solid state.

Having viewed the general features of the whole iron-carbon series we will divide the diagram into portions convenient for a fuller discussion taking first that part lying to the left of the point E, which corresponds to 1.70 per cent carbon. This portion of the iron-carbon diagram pictures the constitutional changes in the alloys known as the steels.

In order to discuss the constitution of these iron-carbon alloys containing less than 1.70 per cent carbon it will first be necessary to define and describe the several metallographic constituents present in these alloys in their normal state. When we speak of a steel being in the normal state we mean that all of the constitutional changes characteristic of the metal have occurred and the constituents are in stable equilibrium. This normal state is usually attained by hot working followed by heating above the critical range (the line GOSE, Fig. 22) with slow normal cooling through the range.

We must be careful, in speaking of a steel being in the normal state, not to confuse the expression normal state with the term normalize as used in heat treatment which ordinarily denotes

⁵³See Fig. 9, Part III, this series. TRANSACTIONS, August, 1926, page 269.

heating to a point well above the critical range followed by moderately rapid cooling as in air.

THE METALLOGRAPHIC CONSTITUENTS IN NORMAL STEELS

We are considering steel to be an alloy of iron and carbon containing between 0.01 and 1.70 per cent carbon. For the present we are not considering the other elements, manganese, sulphur, phosphorus and silicon, always present in small amounts, nor such metals as nickel, chromium, vanadium and others present in the alloy steels.

We have noted that all of the carbon combines with iron to form the chemical compound iron-carbide, Fe_3C . If this is the case, steel is made up of two constituents, iron and iron-carbide. For the present this may be accepted as true.

To pure carbon-free iron, metallographists have given the name *ferrite*. Actually pure iron at atmospheric temperature holds a small amount of iron carbide in solution equivalent to about 0.05 per cent carbon. This small amount can be neglected for the present. Ferrite crystallizes in the cubic system. If the process of crystallization was unrestrained the ferrite would form perfect cubes. We have seen, however, that crystallization starts at numerous centers simultaneously, hence the crystals are ordinarily irregular polygonal grains. Their appearance is shown in Fig. 23⁵⁴.

The metallographical term ferrite refers to carbon-free iron in the alpha state; that is iron that has undergone its last allotropic change⁵⁵. Sauveur states that ferrite (pure alpha iron) has a tensile strength of approximately 40,000 pounds per square inch, an elongation of about 50 per cent in 2 inches, and a Brinell hardness of about 80. Pure ferrite has no hardening power, that is, it is unaffected by heat treatment.

The chemical compound iron carbide, Fe_3C , is known as *cementite*. It is thought that cementite is extremely hard and brittle, as much so as glass. Sauveur assigns the following physical properties to cementite: tensile strength approximately 5,000 pounds per square inch; elongation in inches, none; Brinell hardness greater than 600. Aside from its chemical composition and high hardness the properties of cementite are largely conjectural.

⁵⁴Unless otherwise credited, all photomicrographs are from the metallurgical files, Air Corps, McCook Field.

⁵⁵See Part I, this series. TRANSACTIONS, June, 1926, page 951.

little is known definitely concerning this constituent.

SOLUBILITY OF CARBON IN IRON

In the previous chapter we discussed the solidification of binary alloys whose component metals were (1) soluble in the molten and insoluble in the solid state resulting in eutectic alloys, and (2) soluble in the molten and soluble in the solid state resulting in solid solutions.

In the case of the binary alloys of iron and iron carbide, both conditions are present.

In the molten state iron carbide is soluble in iron. The solubility increases with the temperature until at about 3300 degrees Fahr. (1820 degrees Cent.) the melt consists wholly of iron carbide. As the temperature falls the solubility decreases until at 2065 degrees Fahr. (1130 degrees Cent.) 4.3 per cent carbon, equivalent to 64.5 per cent iron carbide, is soluble. This is the eutectic which solidifies at this constant temperature.

One of the constituents of this eutectic is a solid solution of iron carbide in iron. The other is iron carbide. The maximum solubility of iron for iron carbide in the solid state is 25.5 per cent Fe_3C or 1.70 per cent carbon. The solubility of iron for iron carbide in the solid state, also varies with the temperature. At 2065 degrees Fahr. (1130 degrees Cent.) the maximum of 1.70 per cent carbon (25.5 per cent Fe_3C) is soluble. At atmospheric temperature it is practically nil.

Thus we see that in the liquid state up to 6.67 per cent carbon (100 per cent Fe_3C) is soluble in iron, but in the solid state the maximum solubility is only 1.70 per cent carbon (25.5 per cent Fe_3C).

Referring for a moment to Fig. 22 we note that the upper part of the diagram has almost exact resemblance to the cadmium-bismuth diagram which illustrated the solidification of binary alloys soluble in the molten but insoluble in the solid state. The constituents in molten iron are iron and iron carbide in liquid solution. If we cool an alloy containing 3 per cent carbon (M Fig. 22), at point M^1 it starts to solidify. Now the solidification is not by precipitation of solid iron as we would expect but by precipitation of solid iron containing 1.70 per cent carbon in solid solution. If we cool an alloy containing 4.80 per cent carbon (P Fig. 22) when

point P^1 is reached the solidification starts by precipitation of solid cementite Fe_3C .

This preliminary survey of the solidification of the iron carbon alloys is given here to help us understand the solidification of the steels. We will enlarge upon the discussion when we take up the cast iron in a later chapter.

AUSTENITE

In a previous installment we discussed the allotropic changes in pure iron when it is heated or cooled. Reviewing this briefly: above 1650 degrees Fahr. (900 degrees Cent.) pure iron crystallizes as a face-centered cube. When pure iron is cooled slowly from a high temperature, at 1650 degrees Fahr. (900 degrees Cent.) there is an allotropic change and the iron changes in crystal structure from a face-centered to a body-centered cube. The allotropic modification of iron stable above 1650 degrees Fahr. which crystallizes as a face-centered cube is known as gamma iron. On a previous page we noted that carbon (probably as iron carbide) is soluble in iron up to about 1.70 per cent. When iron carbide (or giving it the metallographic name: *cementite*) is in solution in gamma iron it forms a structural constituent known as *austenite*.

In other words, austenite is a solid solution of cementite in gamma iron. It is evident at once that austenite may contain any amount of carbon from a trace to 1.70 per cent. When 1.70 per cent carbon (equivalent to 25.5 per cent iron carbide) is dissolved in gamma iron the austenite is saturated with carbon.

Most steels contain less than 1.70 per cent carbon, hence when the temperature is above the critical range the austenite of these steels is undersaturated. In cast iron the carbon is generally more than 1.70 per cent, hence when the constituent austenite enters into a discussion of cast iron it is always the saturated austenite. Howe uses the term *austenoid* to designate gamma iron containing 1.70 per cent carbon.

We have stated previously that the question of whether or not beta iron exists is still undecided. It will simplify our discussion if we assume that iron does exist in the beta form under certain conditions. The beta iron controversy obviously depends upon the definition of allotropy. An elementary discussion of low carbon steels is made more complex by omitting beta iron from consideration.

The allotropic changes of gamma to beta iron or gamma to alpha iron take place even though cementite is in solution in the iron. In pure iron the allotropic change of gamma iron to beta or alpha iron is one which concerns a rearrangement of the crystal units. Carbon is not present to complicate the change.

Gamma iron will hold cementite in solution. Cementite is insoluble in alpha iron⁵⁶. Hence in the transformation taking place in steel containing carbon there are two factors entering: (1) the rearrangement of the crystal structure, (2) the concentration of the carbon in the remaining austenite. The alpha iron resulting in the allotropic changes from gamma iron is relatively free from cementite. Hence as the alpha iron is formed, the cementite is concentrated in the austenite which is as yet untransformed.

It will be noted from Fig. 22 that in steels containing less than about 0.85 per cent carbon the temperature of which the allotropic change from gamma to beta or alpha iron occurs is progressively lowered along the line GOS as the carbon increases from 0.01 to 0.85 per cent.

With a carbon percentage of 0.85 to 1.70 the temperature of this allotropic change is constant as shown by the horizontal line SK.

Austenite is stable only above the line GOSK, hence it is extremely difficult to retain it at atmospheric temperature. It has been possible by drastic quenching of very high carbon steels to prevent the whole transformation from taking place. There are certain metals when alloyed with iron in large amounts (14 per cent manganese or 25 per cent nickel) that lower the transformation of gamma iron to atmospheric temperature or below. By these means we are able to study austenite and determine its structure and properties.

As the carbon content of austenite may range from 0.01 to 1.70 per cent it is natural to suppose that the physical properties will vary widely. In general austenite is softer than a hardened steel of the same carbon content. In austenite the iron is in the gamma state hence it is not magnetic. Austenitic steels are usually ductile, have relatively low elastic limit and although they are not hard as measured by the Brinell test, they are very resistant to wear. Most of them are machined with great difficulty and some cannot be machined at all.

⁵⁶A small amount of cementite equivalent to about 0.05 per cent carbon is soluble in alpha ferrite. For the present this may be neglected.

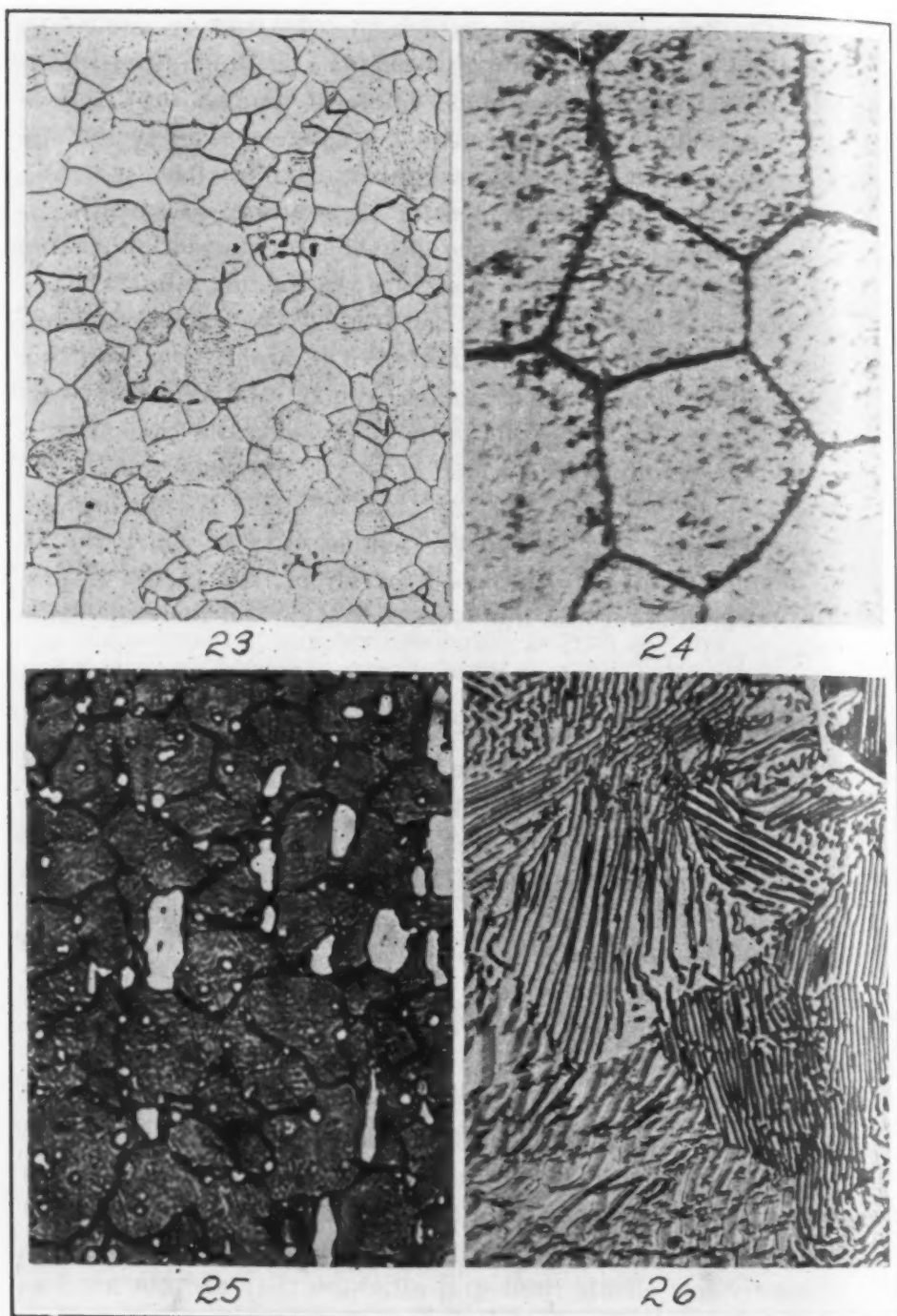


Fig. 23—Photomicrograph of Ferrite in a 0.02 Per Cent Carbon Steel. Mag. 100x. Fig. 24—Photomicrograph Showing Austenite Grains in Steel. 500x. Fig. 25—Photomicrograph Showing Austenite Grains (Dark) Carbides (White). Specimen of Steel Etched with Ferric Chloride in Alcoholic Nitric Acid. 500x. Fig. 26—Photomicrograph of a 0.90 Per Cent Carbon Steel, Showing the Structure of Pearlite at a Magnification of 500x. Etched in Alcoholic Nitric Acid.

The structure of austenite is similar to the structure of other solid solutions and resembles in many respects the structure of pure metals. Figs. 24 and 25 show the microstructure of austenite. In Fig. 24 the large polyhedral grains are characteristic of both solid solutions and pure metals. Fig. 25 shows the structure of a heat treated complex alloy steel. The white particles are carbides embedded in a matrix of austenite.

THE UPPER TRANSFORMATION POINTS IN LOW CARBON STEEL

Let us go back for a moment to the allotropic changes taking place in pure iron. If pure iron is cooled slowly from a high temperature when 1650 degrees Fahr. (900 degrees Cent.) is reached the metal undergoes an allotropic change from gamma to the beta (?) modification. Beta iron is stable until 1415 degrees Fahr. (768 degrees Cent.) is reached when another allotropic change takes place, the beta iron changing to alpha iron, which is stable down to atmospheric temperature.

The temperatures where these allotropic changes take place are known as transformation or critical points. The critical point where the gamma iron changes to beta iron in cooling is known as Ar_3^{57} and where the beta iron changes to alpha iron is known as Ar_2 .

The critical point representing the change from alpha to beta iron in heating is known as Ac_2^{58} and the change from beta to gamma iron as Ac_3 .

The Ac points usually occur at a somewhat higher temperature than the Ar points. This is probably due to lag. When the Ac and Ar points are spoken of collectively they are simply designated by the letter A .

Referring to Fig. 22 it will be seen that the upper critical point Ar_3 for pure iron occurring at 1650 degrees Fahr. (900 degrees Cent.) is noted by the point G , where the coordinate corresponding to zero carbon intersects the temperature coordinate. At the carbon increases it will be noted that the temperature of the Ar_3 transformation decreases along the line GO .

The slanting line GO represents the Ar_3 transformation in steels containing between 0.01 and 0.40 per cent carbon.

⁵⁷r from the French *refroidissement*, meaning cooling.

⁵⁸c from the French *chauffage*, meaning heating.

In pure iron the Ar_2 point where beta iron is changed to alpha iron is noted by the point M on Fig. 22. This temperature remains constant as the carbon increases from 0.01 to 0.40 per cent.

If we investigate transformation points on steels containing between 0.40 and 0.85 per cent carbon by taking cooling curves we will find that there is but one upper arrest instead of two. In other words when the carbon content is 0.45 per cent or above the position of the Ar_3 line has been lowered to the point where it merges with the Ar_2 line. This is shown at the point O in Fig. 22.

The upper or Ar_3 point so prominent in pure iron has diminished in intensity until when the carbon content is about 0.40 per cent it is combined with the Ar_2 point. The transformation points represented by the line OS are known as Ar_{3-2} for cooling and Ac_{3-2} for heating.

The discussion up to this point has concerned the position and causes of the Ar_3 and Ar_{3-2} critical points in pure iron and steels of less than 0.85 per cent carbon, represented on Fig. 22 by the lines GO, MO and OS.

On Fig. 22 there is horizontal line PK across the diagram, the first section of which is designated PS (Ar_1). Obviously this Ar_1 line PS represents an allotropic change in steels containing less than 0.85 per cent carbon. In the most careful determination of transformation points in pure iron, no allotropic change can be detected at 1290 degrees Fahr. (700 degrees Cent.).⁵⁹ It is apparent since pure iron shows no transformation corresponding to the line PS that this transformation must be dependent upon the carbon. By the determination of the transformation occurring at about 1290 degrees Fahr. (700 degrees Cent.) for a large number of pure steels of increasing carbon content it has been found that the intensity of the change at Ar_1 (line PS) as evidenced by the jog in the cooling curve, increases from practically zero for steels of 0.05 per cent carbon and below to a maximum at 0.85 per cent carbon.

Before discussion of what happens when steel is cooled through the Ar_1 point it is necessary to become familiar with the metallographic constituent pearlite.

⁵⁹In Fig. 22 the line PS is located at 1328 degrees Fahr. (725 degrees Cent.). Sauveur gives the location of the line PS (Ar_1) as about 1275 degrees Fahr. and Ac_1 some 50 degrees Fahr. higher.

PEARLITE

If we refer for a moment to Figs. 29 and 30, photomicrographs of carbon steels containing 0.10 and 0.30 per cent carbon respectively, we see that the structure of these steels consists of two constituents; one light and the other dark. In Fig. 30 the higher carbon of the two steels, the dark grains are more numerous than in Fig. 29 the lower carbon steel.

Turning back to Fig. 23, a photomicrograph of a steel containing 0.02 per cent carbon it is evident that only one constituent is present, as all of the grains are light in color. In Fig. 23 the grains are ferrite, alpha iron containing but a trace of carbon in solution. From the appearance we would suppose that in Figs. 29 and 30 the carbon must be concentrated in the darker areas.

If we examine one of these dark areas at higher magnification, a structure similar to that shown in Figs. 26 and 27⁶⁰ is seen. We find that the dark areas containing the carbon are made up of alternate plates or lamellae apparently of two different constituents. What appeared to be one constituent when the steel was examined at a magnification of 100 diameters is really made up of light and dark plates when examined at higher magnification⁶¹.

Because the parallel plates or lamellae often resemble mother-of-pearl in appearance, Howe called this constituent *pearlite*. A close examination of these lamellae will disclose the fact that the plates are cementite, Fe_3C and ferrite. What appears to be a uniform dark-colored grain when examined at low magnification is actually an aggregate of cementite and ferrite; in other words, an aggregate of the chemical compound iron carbide and pure alpha iron.

When a specimen containing lamellar pearlite is etched the acid corrodes the soft ferrite, but does not attack the harder cementite. The cementite stands in relief, and appears white when viewed with a microscope. The ferrite is tarnished and corroded. This together with the shadow cast by the hills of cementite make the ferrite appear dark.

At low magnifications lamellar pearlite appears to be dark gray. In most medium and high carbon steels the pearlite appears very

⁶⁰Fig. 27 and other photomicrographs at high magnification appearing in this series were made by J. L. Hester, photographer and metallographist, Air Corps, McCook Field.

⁶¹Figs. 26 and 27 are photomicrographs of a 0.90 per cent carbon steel specially prepared, so that the plates or lamellae are as large and as uniform as possible. We shall see in a later discussion that the plates are often imperfectly formed.

dark brown or black at low magnification. This is due to the fact that cooling conditions are usually not favorable for the pearlite to assume such an exaggerated parallel arrangement as is shown in Fig. 26. More often the plates are extremely small, irregular

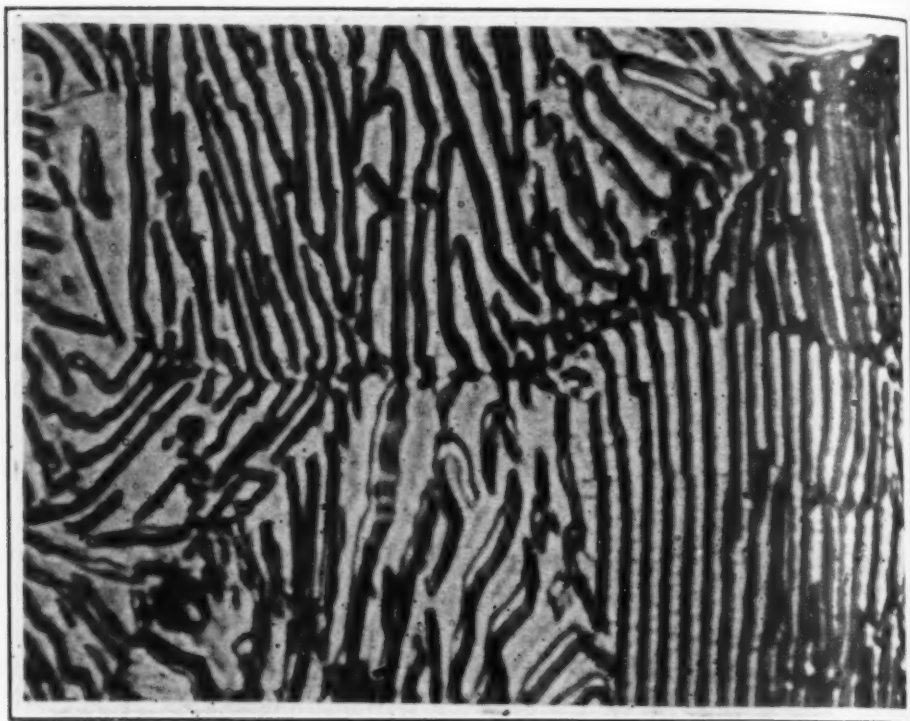


Fig. 27—Photomicrograph of Pearlite in a 0.90 Per Cent Carbon Steel Etched with Alcoholic Nitric Acid. 3000x.

and uneven. Frequently cooling conditions are such that the cementite and ferrite are in a more or less emulsified form and not arranged in parallel plates. When this occurs the aggregate is known as granular pearlite. Between the two extremes of granular pearlite and lamellar pearlite, an infinite variety of form is possible. Fig. 26 at 500 diameters and Fig. 27 at 3000 diameters represent pearlite in which the transformation is complete, the cooling has been slow enough so that steel is in a state approaching complete equilibrium.

If the photomicrographs of pearlite shown in Figs. 26 and 27 are compared with the structure of eutectics illustrated in the previous installment⁶² remarkable similarities will be at once evident. Pearlite and many eutectics are made up of two constituents both of which are visible when viewed by the microscope. A eutectic of

⁶²TRANSACTIONS, August, 1926, page 273.

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two metals such as cadmium-bismuth has a definite fixed amount of both constituents and solidifies at a constant temperature. Pearlite has a definite amount of iron carbide and ferrite. In addition the transformation of the austenite into pearlite occurs at a single and definite temperature. This similarity in the characteristic of eutectic and pearlite has lead to the latter being known as the *eutectoid*.

Pearlite contains about 0.85 per cent carbon equivalent to about 12.5 per cent cementite. Hence pearlite is made up of 12.5 per cent cementite and 87.5 per cent ferrite.

In low and medium carbon steels there is more than 87.5 per cent ferrite present. The ferrite in excess of the amount in the eutectoid ratio (87.5 per cent) is known by the terms free ferrite, excess ferrite, or proeutectoid ferrite.

In steels containing more than 0.85 per cent carbon there is more than 12.5 per cent cementite. The cementite in excess of the eutectoid ratio is known by the same terms, proeutectoid, free, or excess cementite.

Steels containing less than 0.85 per cent carbon are known as *hypoeutectoid* steels. When the carbon is greater than 0.85 per cent they are termed *hypereutectoid*. Some of these terms are used by Howe in his iron-carbon diagram, Fig. 22.

In the next installment we will take up the method of calculating the structural composition of hypo and hypereutectoid steels.

Sauveur gives the following values for the physical properties of pearlitic steel in its normal condition: tensile strength, about 115,000 pounds per square inch; elongation about 10 per cent in two inches; Brinell hardness approximately 200 and hardening power, the maximum.

THE LOWER TRANSFORMATION POINT IN STEEL

The point A_1 occurs in steel containing more than a trace of carbon. It marks the evolution of heat (Ar_1) due to the change of the remaining austenite into pearlite. In steels containing less than 0.40 per cent carbon, when cooled, the transformation at Ar_3 (line GO Fig. 22) is the change of the iron from the gamma form to the beta (?) form. At Ar_2 (line Mo Fig. 22) this beta iron changes to alpha iron. In steels containing between 0.40 and about 0.85 per cent carbon when cooled the transformation at Ar_{3-2} (line OS Fig. 22) is the change from gamma to alpha iron. Opinion differs whether this change takes place directly or whether the

gamma changes to beta and then instantly to alpha.

As pure alpha iron has practically no solvent power for cementite, the allotropic change of the gamma iron at the critical points represented by the lines GO, and OS necessitates that the cementite in solution in the gamma iron be concentrated in the remaining austenite. This concentration continues while the temperature is falling along the line GOS. When point S is reached the residual austenite is of eutectoid composition and changes into pearlite.

In the case of low carbon steels, for instance 0.10 per cent carbon, a large amount of excess ferrite is present. The beginning of the allotropic change from gamma iron to alpha ferrite, Ar_4 is marked by an evolution of heat of considerable intensity. The amount of cementite is relatively small hence by the time the remaining austenite has reached eutectoid composition only a little of this constituent will be left. The transformation of this small amount of austenite into pearlite is accompanied by an evolution of heat of faint intensity.

If the steel contains 0.70 per cent carbon the amount of excess ferrite is small hence the evolution of heat Ar_{3-2} is faint, but now the large amount of residual austenite in transforming into pearlite gives rise to a very marked jog in the cooling curve.

From this and from the thousands of curves run on samples of pure steels, it follows that the evolution of heat at Ar_1 is most marked at point G and decreases until it disappears near the point O. The evolution of heat at Ar_{3-2} is distinct at point O but likewise decreases in intensity and disappears near point S.

The evolution of heat at Ar_1 , zero for pure iron, increases in intensity as the carbon increases until at the eutectoid ratio 0.85 per cent carbon, the evolution is so strong that it causes a perceptible rise in temperature even though the furnace is cooling at a uniform rate. This is called the point of *recalescence*.

CONSTITUTIONAL CHANGES IN LOW CARBON STEELS

Fig. 28 is an enlarged portion of the iron-carbon diagram shown in Fig. 22, reproduced here to facilitate discussion of the constitution of the various steels. The diagram shown in Fig. 28 is the same as the left half of Fig. 22 except that the left side of the Ar_1 line was lettered D in error instead of P.

Four ordinates are drawn through Fig. 28. These are lettered W, X, Y and Z, and refer to steels containing 0.20, 0.50, 0.85 and

1.30 per cent carbon. The first one, W, is representative of the low carbon or mild steels, which exhibit three critical points in cooling, Ar_3 , Ar_2 , and Ar_1 . The diagram shown in Fig. 28 represents steels

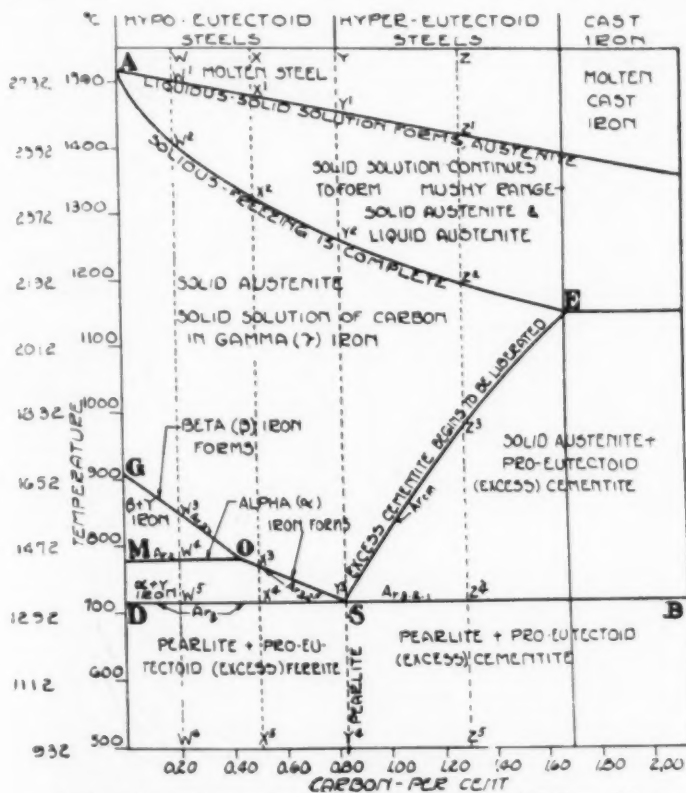


Fig. 28—Portion of the Iron-Carbon Equilibrium Diagram Representing Steels in Their Normal State.

in their normal condition, cooled slowly so that all structural constituents are in stable equilibrium. This postulates the carbon in the form of cementite, Fe_3C . In cast irons, cementite is usually unstable tending to break down into iron and graphite. For the present this is not important.

The solidification and transformations occurring when a 0.20 per cent carbon steel is cooled from the molten is shown by following the ordinate W. At 2865 degrees Fahr. (1575 degrees Cent.), point W, we have a solution of carbon in molten iron. As this solution cools no change takes place until 2732 degrees Fahr. (1500 degrees Cent.), point W^1 , is reached. At this temperature austenite, the solid solution of carbon in iron, starts to separate out. In the austenite that separates first, the carbon content is less than 0.20 per cent. The remaining molten metal is thus enriched

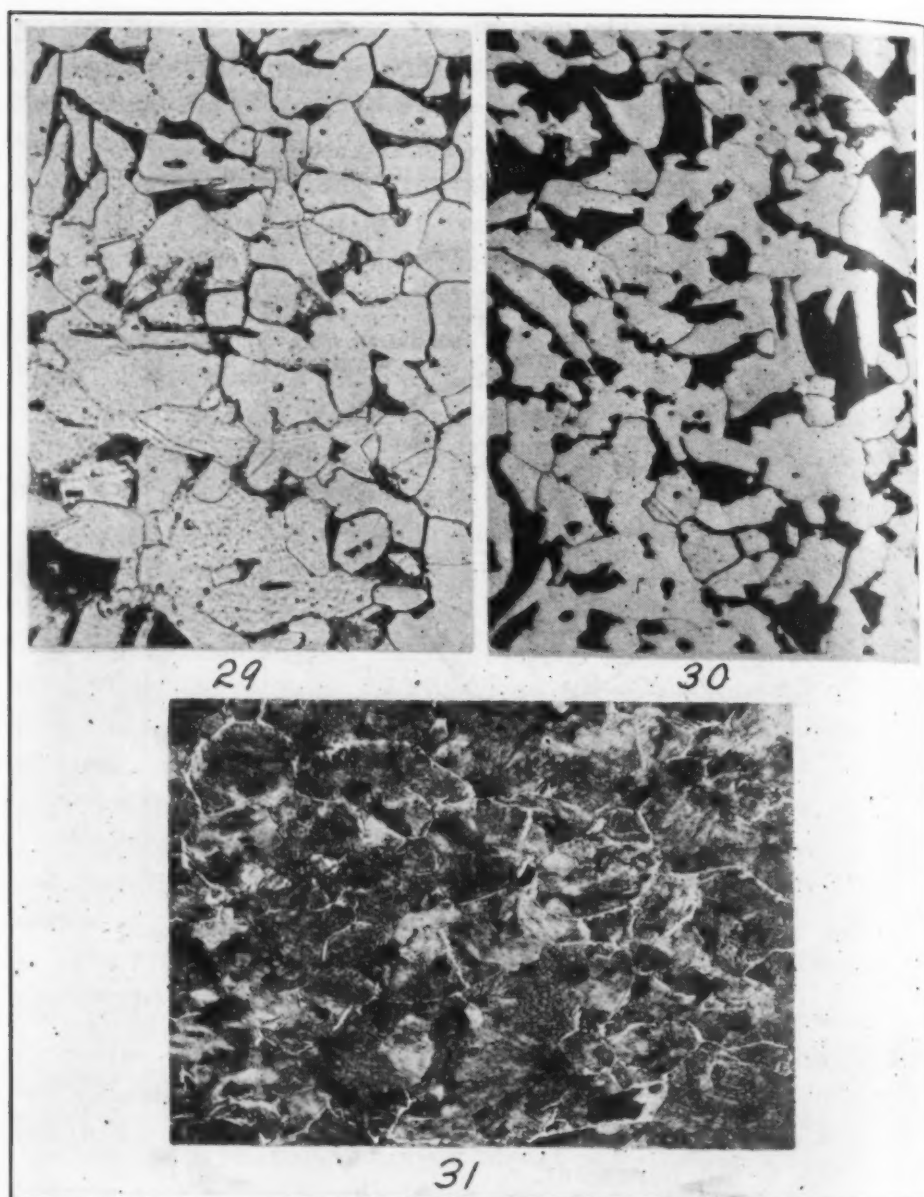
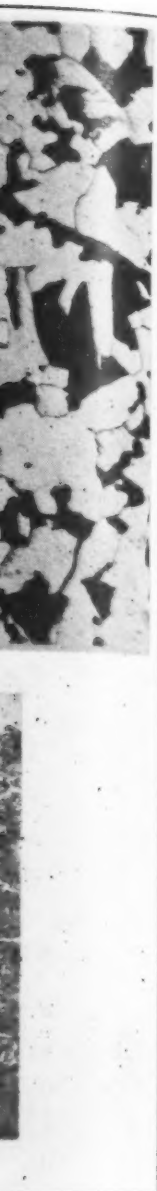


Fig. 29—Photomicrograph of Low Carbon Steel Having a Carbon Content of 0.10 Per Cent. The White Constituent is Ferrite, the Dark Constituent is Pearlite. Fig. 30—Photomicrograph of a Medium Carbon Steel Having a Carbon Content of 0.30 Per Cent. The White Constituent is Ferrite, the Dark Constituent is Pearlite. Etched in Alcoholic Nitric Acid. 100x. Fig. 31—Photomicrograph of Medium Carbon Steel Having a Carbon Content of 0.55 Per Cent. The Dark Constituent is Pearlite, the Light Constituent is Ferrite. 100x.

in carbon. As the metal cools from W^1 to W^2 solid austenite of increasing carbon content (measured by the abscissae of the line AE) forms until at 2552 degrees Fahr. (1400 degrees Cent.), point W^2 , all of the metal is solid.



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As the solid austenite cools from W^2 to W^3 , the heterogeneous austenite becomes homogeneous by diffusion of the carbon from the carbon-rich austenite into the carbon-poor austenite. It must be remembered that when the point W^1 is reached, solidification starts at a large number of centers at once. In this mushy stage, W^1 - W^2 , the physical condition of the metal may be likened to whole milk, in which the solid butter fat is highly dispersed throughout the mass of milk in the form of an emulsion. When the metal reaches W^2 this emulsion solidifies in its highly dispersed state. Thus the distance that the carbon must travel in diffusing from the carbon-rich austenite to the carbon-poor austenite is hardly greater than 0.0001 to 0.000001 millimeters.

Except for the diffusion of the carbon there is no change in the austenite until a temperature of about 1580 degrees Fahr. (860 degrees Cent.), point W^3 , is reached. Here a portion of gamma iron, practically free from carbon, undergoes an allotropic change into beta iron. This change continues to the line MO, point W^4 , where this beta iron changes to alpha iron with evolution of heat. As these changes are taking place, the remaining gamma iron is being gradually enriched in carbon until the remaining austenite is of eutectoid composition (0.85 per cent carbon). At 1328 degrees Fahr. (720 degrees Cent.), line DS, point W^5 , the austenite of eutectoid composition is transformed into pearlite. Structural changes are now complete and the steel which consists of pearlite and excess ferrite cools unchanged to atmospheric temperature.

CONSTITUTIONAL CHANGES IN MEDIUM CARBON AND EUTECTOID STEELS

The solidification of a 0.40 per cent carbon steel begins at about 2714 degrees Fahr. (1490 degrees Cent.) and is completed at 2416 degrees Fahr. (1325 degrees Cent.). It will be noted that the mushy range, X^1 - X^3 , is of longer duration. After the metal is all solid, carbon diffusion continues while the steel is cooling from X^2 to X^3 . At this point, Ar_{3-2} , begins the allotropic change of relatively carbon-free gamma iron to alpha iron and the resultant enrichment of the remaining gamma iron in carbon. It is not certain whether the change is from gamma iron to alpha iron or from gamma to beta and then instantly to alpha.

Between X^3 and X^4 the change from gamma to alpha continues. At 1328 degrees Fahr. (725 degrees Cent.) the remaining austenite,

now of eutectoid composition, is transformed to pearlite.

Steel containing 0.85 per cent carbon (the eutectoid ratio) begins solidifying at about 2695 degrees Fahr. (1480 degrees Cent.), Y^1 , and is completely solid at 2280 degrees Fahr. (1250 degrees Cent.) point Y^2 . With this carbon content the mushy range is still greater.

After solidification is complete the austenite cools unchanged to 1328 degrees Fahr. (720 degrees Cent.), point Y^3 , where the whole of the gamma iron is changed to alpha and the austenite transformed into pearlite.

STRUCTURE OF LOW AND MEDIUM CARBON STEELS

The structure of low and medium carbon steels when in their normal condition consists of free ferrite and pearlite. When the steel contains 0.05 per cent carbon or less the structure will consist wholly of irregular polygonal grains of ferrite (see Fig. 23). With a carbon content of 10 per cent a few dark areas appear. Fig. 29 shows the microstructure of a 10 per cent carbon steel. As the carbon increases the amount of pearlite increases rapidly⁶³ as shown in the accompanying table from Sauveur⁶⁴.

Carbon Per Cent	Total Cementite Per cent	Total Ferrite Per cent	Pearlite Per cent	Free Ferrite Per cent
0.10	1.5	98.5	11.7	88.3
0.20	3.0	97.0	23.4	76.6
0.30	4.5	95.5	35.1	64.9
0.40	6.0	94.0	46.8	53.2
0.50	7.5	92.5	58.5	41.5
0.60	9.0	91.0	70.2	29.8
0.70	10.5	89.5	81.9	18.1
0.80	12.0	88.0	93.6	6.4

In Fig. 29, the pearlite is 11.7 per cent of the total; in Fig. 30, a 0.30 per cent carbon steel, it is 35.1 per cent of the total.

Fig. 31 shows the structure of a steel containing 0.50 per cent carbon. This steel contains 58.5 per cent of pearlite and 41.5 per cent free ferrite. In this case the ferrite forms envelopes around the grains and is distributed in small particles in the grains themselves.

In steels containing between 0.50 and 0.70 per cent carbon the microstructure is oft times deceptive in that the amount of

⁶³The method of calculating the amount of the various constituents will be given in the next installment.

⁶⁴Metallurgy and Heat Treatment of Iron and Steel, 1926, page 63.

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pearlite nearly always appears to be greatly in excess of the amount actually present. Steels containing 0.65 to 0.75 per cent carbon usually appear to be composed wholly of pearlite when actually about 20 or 25 per cent free ferrite is present.

This is in sharp contrast to the very low carbon steels. When a steel contains 0.10 per cent carbon only 11.7 per cent pearlite is present but this relatively small amount is very evident in the microstructure (see Fig. 29).

Due to the fact that the structure as shown by the microscope does not always indicate the true amount of the constituents present, it is well to use caution when estimating chemical composition by the microstructure.

Editors Note—The next installment will discuss the constitution of the high carbon steels and the methods of calculating the amount of structural constituents present in all steels.

ON ELECTRIC STEEL MELTING

BY BIRGER EGEBERG

(Continued from Page 408)

tion of rock drills would not be at all suitable for the manufacture of dies; and steel manufactured for the production of heavy milling cutters would not be the best obtainable for the manufacture of taps even though the analysis in each case was the same. As it is entirely possible by varying methods of manufacture to produce steels which will give excellent service in particular lines, it is well to recognize that "quality" of steel as deduced from the service secured upon an individual type of tools cannot be used as a general term.

DR. B. EGEBERG: In conclusion, I want to thank the gentlemen who took part in the discussion for their remarks. The precautions mentioned by Mr. German in order to insure a high quality steel are familiar to every steel-melter and are not touched upon in my paper because it was not my intention to deal with the regular methods in steel-making. My intention was to throw some light upon the phenomena that sometimes occur irrespective of the very best of melting practice, which phenomena are not prevented by such common methods nor enclosed or even indicated by such spoon tests as mentioned by Mr. German. Especially I want to thank Mr. DeLong for his remarks that enclose much truth. However, the changes in manufacture mentioned by Mr. DeLong in order to make the steel fitted for a special purpose are intentional, whereas, the phenomena I have discussed in my paper to some extent at least are outside the control of the manufacturer and which to the best of my knowledge have never improved the steel for any particular purpose.

REPORT OF SUB-COMMITTEE ON TOOL STEEL

IN the May 1925 issue of TRANSACTIONS, there was published a Tentative Recommended Practice for the Heat Treatment of Taps and Milling Cutters. This recommended practice was compiled by the sub-committee for the heat treatment of Tool Steel. After completing this report, the Recommended Practice Committee assigned the sub-committee the problem of compiling a recommended practice for the heat treatment of plain carbon and alloy steel die blocks.

The work of the sub-committee is based upon a survey which was made among the die block manufacturers, steel mills, and individuals who are experts in the die block industry. The report was first submitted to various authorities and technical organizations for the purpose of obtaining constructive comments and suggestions.

These suggestions were then discussed at a meeting of the sub-committee and the report revised in the light of the suggestions received.

There are a large number of die block compositions that work equally as well as those considered by the committee, but of course, all compositions could not be given consideration in this report. The following report will, without a doubt, be of valuable assistance to the industry.

The recommended practice which follows is tentative, and will remain so until such time as it is adopted as a standard recommended practice of the Society by the Recommended Practice Committee, and the Board of Directors.

The personnel of the committee is as follows:

W. J. Merten, Chairman

DuRay Smith

C. I. Neidringhaus

W. H. Phillips

J. P. Gill

J. Trautman, Jr.

C. M. Johnson,

The Tool Steel Committee is indebted to a number of individuals and companies for their assistance and willing co-operation in compiling these recommended practices.

TENTATIVE RECOMMENDED PRACTICES FOR THE
HEAT TREATMENT OF PLAIN AND ALLOY
STEEL DIE BLOCKS¹

GENERAL

THESE recommended practices cover the process to be followed in the heat treatment of die blocks made from plain carbon and alloy steels, and must not be applied to die blocks having chemical compositions other than given in Tables I, II, V and VII, as listed in these recommended practices:

It is not recommended that these steels are the most suitable for die blocks; there are many other steels used that are equally as satisfactory, but, of course, the heat treatments given in these recommended practices cannot be applied.

Prior to any heat treatment, die blocks should have received hot forging on the six sides, in order to more effectively refine the grain and lessen the tendency toward directional structures.

When quenching die blocks, it is important that the quenching bath be sufficiently agitated to avoid the formation of gas pockets. When air hardening, the air should be dry and the blast so directed that the air strikes the face of the block uniformly.

Tentative Recommended Practice for the Heat Treatment of
Cold and Hot Forming Die Blocks (Plain Carbon)

Chemical Composition—There are five classes of carbon steels generally used for die blocks, the chemical compositions of which are given in Table I.

Normalizing—The normalizing temperatures, directions for heating and directions for cooling are given in Table III.

The temperature of the furnace used for this heat treatment should not be over 700 degrees Fahr. at the time the die blocks are charged into it. Cool the blocks in air until they are below the lower critical point.

Annealing and Spheroidizing—The annealing and spheroidizing temperatures, directions for heating, and directions for cooling are given in Table III.

¹This is a tentative Recommended Practice, approved by the Recommended Practice Committee of the A. S. S. T. and will remain tentative until it is adopted by the Recommended Practice Committee and Board of Directors. The committee was composed of four users and three manufacturers as follows: W. J. Merten, Chairman, C. I. Neidringhaus, W. H. Phillips, Du Ray Smith; Manufacturers: C. M. Johnson, J. Trautman, Jr., and J. P. Gill.

The Tool Steel Committee is indebted to a number of individuals and companies for their assistance and willing co-operation in compiling these recommended practices.

Cool the furnace charge slowly in furnace until the blocks become black.²

Hardening—The quenching temperature, the time heating, the time at heat, and the quenching medium used for these die blocks are given in Table III.

The block is immersed in water to approximately one inch below the deepest part of the impression and held in the water until

Table I
Approximate Chemical Composition for Carbon Steel Die Blocks

Die Block No.	Application or Type	C	Mn	Si	P	S
I	Carbon Die Block	0.60-0.75	0.20-0.40	0.15-0.30	0.030	0.030
II	Cold Forming Dies ¹ Ordinary Hammer Die Block	0.75-0.90	0.20-0.40	0.15-0.30	0.030	0.030
III	Cold Forming Dies ¹	0.90-1.05	0.20-0.40	0.15-0.30	0.030	0.030
IV	Hot Forming Dies	1.05-1.20	0.20-0.40	0.15-0.30	0.030	0.030
V	Carbon Die Block	0.50-0.65	0.60-0.80	0.15-0.30	0.030	0.030

¹These steels may or may not contain vanadium up to 0.30 per cent.

Table II
Approximate Chemical Composition for Alloy Steel Die Blocks

Die Block No.	Application	C	Mn	Si	P	S	Cr	Ni	Mo	V	W
VI	Drop Hammer Die Block	0.50-0.70	0.40-0.80	0.15-0.30	0.030	0.030	0.60-1.30	1.00-2.00			
VII	Hot Forming Die Block	0.60-0.70	0.50-0.80				0.75-1.00		0.60-0.90		
VIII	Hot Work in General	0.30-0.45	0.25-0.35	0.15-0.30	0.020	0.020	3.25-3.50			6.30-9.00	9.00-11.00
IX	Oil or Air Hardening Die Block	0.50-0.70	0.50-0.80				0.75-1.00	1.00-2.00	0.60-0.90		
X	Hot Working and Shock-Resisting Die Block for Drop Forging Small Parts	0.55-0.50	0.20-0.35	0.15-0.30	0.030	0.030	0.50-1.50			0.20-0.40	1.50-2.00
XI	Hot Pressing Die Steel ¹	0.85-1.05	0.15-0.35	0.15-0.30	0.030	0.030	3.00-4.50			See Footnote 2	
XII	Drop Hammer Die Blocks	0.50-0.70	0.40-0.80	0.15-0.30	0.030	0.030	0.50-1.00	1.00-2.00	0.15-0.30		

¹This steel should not be used where it will be subjected to shocks.

²This steel may or may not contain vanadium.

it has cooled down to approximately 700 degrees Fahr. or slightly below a red heat. It is then quenched entirely in oil.³

²To test the soundness of the steel (structural condition and imperfections) the block may be quenched completely after the normalizing and spheroidizing operations. The block is then annealed as directed in Table III.

³Die blocks that are approximately a six-inch cube or under may be quenched entirely in water and cooled to about 700 degrees Fahr. (slightly below a red heat). They are then withdrawn and cooled in oil to a temperature of approximately 200 degrees Fahr., and immediately tempered to desired hardness.

TEMPERING

1. **Tempering Hot Forming Die Blocks**—After quenching, the blocks are tempered immediately at the proper temperature, depending upon the hardness desired. A scleroscope reading of 50 to 55 is suggested; the approximate Brinell hardness number is 300 to 325.

2. **Tempering Cold Forming Die Blocks**—After quenching, the blocks are tempered immediately at the proper temperature, depending upon the hardness desired. A scleroscope reading of 70 to 80 is suggested; the approximate Brinell hardness number is 425 to 475.

Tentative Recommended Practice for the Heat Treatment of Alloy Steel Die Blocks (See General Remarks on Page 477)

Normalizing—Directions for the normalizing of die blocks Nos. VI to XII (except No. VIII, which is not normalized) are given in Table IV. The chemical compositions for these steels are given in Table II. When normalizing die block steel number IX, it should not be allowed to become cold but placed in the furnace for the annealing and spheroidizing operations when the temperature has dropped to approximately 400 degrees Fahr. Cool the blocks in the air until they are below the lower critical point.

The temperature of the furnace used for this heat treatment should not be over 700 degrees Fahr. at the time the die blocks are charged into it.

Annealing and Spheroidizing—For annealing and spheroidizing of the alloy blocks, heat to the temperatures given in Table IV and hold at these temperatures for the time specified.

Hardening—Unless otherwise stated below, heat die blocks numbers VI to XII to the hardening temperatures given in Table IV and hold at these temperatures before quenching for the time specified.

Preheating for Hardening (Die Block No. VIII)—Die blocks made from this steel should first be preheated before hardening. They are heated to 1500-1550 degrees Fahr. and held at this temperature for one hour for every inch of diameter or thickness. The blocks are then heated quickly to the hardening temperature.

Hardening (Die Block No. VIII)—When the die blocks have been preheated thoroughly, they are heated quickly to the hardening temperature as shown in Table IV and cooled in air or

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P	S
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0.030	0.030
0.030	0.030
0.030	0.030

e Blocks

V	W
6.30	9.60
0.60	11.00
0.20	1.50
0.40	2.00

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Table III
Heat Treatments for Carbon Steel Die Blocks
Cold and Hot Forming Die Blocks

No. as Listed Table I	Normalizing			Annealing and Spheroidizing ⁴				Hardening			Tempering Temperature Degrees Fahr.		
	Temp. Deg. F.	Time		Cool in	Temp. Deg. F.	Time		Cool ² in	Temp. Deg. F.	Time			
		Heating	At Heat ⁵			Heating	At Heat			Heating		At Heat	
I	1475-1550	1 hour per in. of dia. or thickness ³	½ of total heating time	Air	1350-1375	1 hour for every inch of dia. or thickness, plus 1 hr.	1 hour per in. of dia. or thickness	Furnace	1450-1500	1 hour per ½ in. of dia. or thickness	heating time	Water	To desired Hardness
II	1550-1575	1 hour per in. of dia. or thickness ³	½ of total heating time	Air	1300-1350	1 hour for every inch of dia. or thickness, plus 1 hr.	1 hour per in. of dia. or thickness	Furnace	1425-1475	1 hour per ½ in. of dia. or thickness	heating time	Water	To desired Hardness
III and IV	1575-1650	1 hour per in. of dia. or thickness ³	½ of total heating time	Air	1300-1350	1 hour for every inch of dia. or thickness, plus 1 hr.	1 hour per in. of dia. or thickness	Furnace	1400-1450 ⁴	1 hour per ½ in. of dia. or thickness	heating time	Water	To desired Hardness
V	1450-1500	1 hour per in. of dia. or thickness ³	½ of total heating time	Air	1300-1350	1 hour for every inch of dia. or thickness, plus 1 hr.	1 hour per in. of dia. or thickness	Furnace	1400-1425	1 hour per ½ in. of dia. or thickness	heating time	Water	To desired Hardness

¹It is assumed for this heat treatment that the die block was first normalized.

²After this heat treatment, the scleroscope reading should not be over 30.

³The smallest dimension of the block should be taken as the thickness.

⁴These heat treatments do not apply to cold heading dies.

⁵When normalizing large blocks, the time of holding at heat should be increased in order to refine the center of the block.

Table IV
Heat Treatment for Alloy Steel Die Blocks

No. as Listed in Table II	Normalizing Time				Annealing and Spheroidizing ¹				Hardening			
	Time		Temp. Deg. F.	Cool in	Time		Temp. Deg. F.	Max. Shore Read.	Time		Temp. Deg. F.	Quench. Medium
	Heating	At Heat			Heating	At Heat			Heating	At Heat		
VI	1550-1600	1 hour per in. of dia. or thickness	1/2 of heating time	Air	1325-1375	1 hr. per in. of dia. or thickness plus 1 hr.	1500-1550 ²	35	1 hour per in. of dia. or thickness	1/2 of heating time	1500-1550 ²	Oil ³ min. temp. of 100 deg. F.
VII	1650-1675	1 hour per in. of dia. or thickness	1/2 of heating time	Air	1350-1400	1 1/4 hrs. per in. of dia. or thickness	1575-1625	35	1 1/4 hrs. per in. of dia. or thickness	1/2 of heating time	1575-1625	Oil ⁴
VIII					1600-1650 ⁵	1 hr. per in. of dia. or thickness	1900-2200 ⁵	35			1900-2200 ⁵	Air or Oil
IX (a)	1600-1650	1 hour per in. of dia. or thickness	1/2 of heating time	Air	1350-1400	1 1/4 hrs. per in. of dia. or thickness	1550-1600	35	1 1/4 hrs. per in. of dia. or thickness	1/2 of heating time	1550-1600	Air
(b)	1600-1650	1 hour per in. of dia. or thickness	1/2 of heating time	Air	1350-1400	1 1/4 hrs. per in. of dia. or thickness	1475-1525	35	1 1/4 hrs. per in. of dia. or thickness	1/2 of heating time	1475-1525	Oil
X					1450-1500	1 1/4 hrs. per in. of dia. or thickness	1600-1700	35	1 1/4 hrs. per in. of dia. or thickness	1/2 of heating time	1600-1700	Oil
XI					1450-1500	1 1/4 hrs. per in. of dia. or thickness	1550-1700 ⁵	35	1 1/4 hrs. per in. of dia. or thickness	1/2 of heating time	1550-1700 ⁵	Air or Oil ⁶
XII	1550-1575	1 hour per in. of dia. or thickness	1/2 of heating time	Air	1350-1400	1 1/4 hrs. per in. of dia. or thickness	1475-1525	35	1 1/4 hrs. per in. of dia. or thickness	1/2 of heating time	1475-1525	Oil ³

Foot Notes for Table IV will be found on Page 483.

¹It is assumed for this heat treatment that the die block was first normalized.

²After this heat treatment, the scleroscope reading should not be over 30.

³The smallest dimension of the block should be taken as the thickness.

⁴These heat treatments do not apply to cold heading dies.

⁵When normalizing large blocks, the time of holding at heat should be increased in order to refine the center of the block.

quenched into oil.

Hardening (Die Block No. IX)—For hardening, the die blocks should be heated to the temperature as shown in Table IV and held for the time specified. With intricate impressions, the blocks should be pack hardened and cooled with a blast of dry air. Cool to about 400 degrees Fahr. and temper at 1000 degrees Fahr.

Tempering—After quenching, the die blocks are tempered immediately at the proper temperature, depending upon the hardness desired.

The suggested scleroscope readings, after tempering, for a few of the blocks are as follows:

Block No.	Scleroscope Reading	Approximate Brinell Hardness Number
VI	50 to 55	300 to 325
VII	48 to 55	290 to 325
XII	50 to 55	300 to 325

When air quenched die blocks are not tempered, the desired scleroscope reading is 42 to 48; approximate Brinell hardness number is 260 to 290.

Before using a die of analysis No. VIII, it should first be heated to approximately 200 degrees Fahr.

Tentative Recommended Practice for the Heat Treatment of Cold Heading Dies—Block No. XIII (See General Remarks on Page 477)

Cold heading dies usually have the chemical composition as given in Table V.

Table V
Approximate Chemical Composition of Cold Heading Dies

Die Block No.	Application	C	Mn	Si	P	S
XIII	Cold Heading	0.90-1.05	0.20-0.40	0.15-0.30	0.030	0.030

Normalizing—Cold heading dies are normalized at the temperature given in Table VI and held for the time specified.

Annealing and Spheroidizing—The dies are heated to the temperature given in Table VI and held for the time specified.

Preheating—Cold heading dies are preheated at 1400 degrees Fahr. before hardening.

Hardening—Heat the dies to the temperature given in Table VI and hold for the time specified.

These dies are quenched into water, but removed from the

Table VI
Heat Treatments for Cold Heading Dies

No. as Listed in Table V	Normalizing				Annealing and Spheroidizing ¹				Hardening ²			
	Time		Temp. Deg. F.	Cool in	Time		Temp. Deg. F.	Cool in	Time		Temp. Deg. F.	Quench Medium
	Heating	At Heat			Heating	At Heat			Heating	At Heat		
XIII	1575-1650	1 hour per 1/2 in. of dia. or thickness	1 hour per 1/2 in. of dia. or thickness	Air	1300-1350	1 hour per 1/2 in. of dia. or thickness	1650	Furnace	1 hour per 1/2 in. of dia. or thickness	1/2 heating time	500-600	Water

¹It is assumed for this heat treatment that the die block was first normalized.

²This block should be preheated at 1400 degrees Fahr. before hardening. This steel is purposely overheated to develop a coarse grained structure which has been found suitable to give the best results for most classes of cold-heading dies.

³After this heat treatment the scleroscope reading should not be over 30.

Foot Notes for Table IV

¹It is assumed for this heat treatment that the die block was first normalized.

²From these temperatures, cool slowly to a black heat in the furnace.

³After quenching the block entirely in oil, it is sometimes customary not to allow the block to reach the temperature of the oil, but remove it while still hot enough, so that the oil smokes freely on the surface of the block, but does not flash. While smoking hot, the block is then put at once into the tempering furnace. This is to prevent breakage of blocks.

⁴Small blocks of approximately a six-inch cube or under, should be quenched into oil which has first been heated to 150 degrees Fahr.

⁵For air quenching, heat to 1550-1600 degrees Fahr. The same rules for heating and holding at heat apply.

⁶This is an annealing operation, and the blocks should either be pack annealed or the furnace bottom should be covered with charcoal. Retard the cooling at 1350-1400 degrees Fahr. for sufficient time to bring about proper annealing structure; this applies particularly to the higher carbon ranges.

⁷See direction for preheating this die block in the text.

⁸At high temperatures this steel is susceptible to grain growth. It is best to hold for a longer time at the lower temperature. If air cooling is employed, preheat at 1600 degrees Fahr., then heat quickly to 1700 degrees Fahr.

⁹Quench into oil or air, depending upon the size of the die block.

¹⁰If oil hardened, temper between 800 and 1000 degrees Fahr. When air hardened, this die block may be tempered as high as 750 degrees Fahr.

bath when cooled to a tempearture of about 700 or 800 degrees Fahr. The cooling is completed in oil.

Tempering—After quenching, the dies are tempered immediately at a temperature of 500 to 600 degrees Fahr.

Table VII
Approximate Chemincal Composition of Die Blocks for Silverware

Die Block No.	C	P	Mn	S	Si	Ni	Cr	V	W
XIV	0.90	0.03	0.20-0.30	0.03	0.10-0.20				
XV	0.90-1.00	0.025	0.20-0.30	0.025	0.10-0.20				
XVI	1.00-1.10	0.02	0.25-0.30	0.02	0.10				
XVII	1.10-1.20	0.03	0.25-0.35	0.03	0.15-0.25				
XVIII	0.40-0.50	0.03	0.25-0.35	0.03	0.15-0.25	1.25	1.00		
XIX	0.70-0.80	0.02	0.25-0.35	0.02	0.15-0.25			0.25	
XX	0.80-0.90	0.02	0.25-0.35	0.02	0.15-0.25			0.25	
XXI	0.90-1.00	0.025	0.60-0.70	0.025	0.15-0.25		1.25	0.25	
XXII	0.70-0.80	0.025	0.55-0.60	0.025	0.15-0.25	1.30-1.50	0.65-0.75		
XXIII	0.85-0.95	0.025	0.75-1.00	0.025	0.15-0.25		0.25-0.50		0.25-0.50

KIND OF WORK STRUCK BY ABOVE STEELS

- XIV—Hot Forging Knife Handles.
- XV—Nickel Flat Ware and Sterling.
- XVI—Steel.
- XVII—Nickel Flat Ware and Steel.
- XVIII—Steel.
- XIX—Hot Forging Knife Handles.
- XX—Nickel Flat Ware and Steel.
- XXI—Sterling, Nickel Flat Ware and Steel.
- XXII—Steel for Small Dies with Shallow Impressions.
- XXIII—Oil Hardening Jewellers' Dies.

Tentative Recommended Practice for the Heat Treatment of Die Blocks for Silverware

GENERAL

This recommended practice covers the process to be followed in the heat treatment of silverware die blocks made from steels having a chemical composition as given in Table VII. The base metal to be stamped may be steel, nickel-silver, or sterling.

For the best results in heat treating, these blocks should have received hot forging on six sides as recommended for the other die blocks in the first part of this recommended practice.

When quenching these die blocks it is important that the quenching bath or die block be agitated sufficiently to avoid the formation of gas pockets.

In the manufacture of silverware, it is general practice to either cut master dies or make hobs from master hobs. In either case, the steel must be in a soft condition. To accomplish this condition, the dies are packed and heated to 1500 degrees Fahr., which

Table VIII
Heat Treatments for Steel Die Blocks for Silverware

No. as Listed in Table VII	Normalizing				Annealing and Spheroidizing				Hardening*			
	Time		Temp. Deg. F.	Cool in	Time		Temp. Deg. F.	Max. Shore Read.	Time		Quench. Medium	Tempering Temperature Deg. Fahr.
	Heating	At Heat			Heating	At Heat			Heating	At Heat		
XIV	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time	1550- 1600	Air	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time	1325- 1375		1 hour per in. of dia. or thick- ness	1/2 of heat- ing time	Brine or Water	350-400 for 1 hour
XV	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time	1475- 1525	Air	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time	1375- 1400	35	1 hour per in. of dia. or thick- ness	1/2 of heat- ing time	Water	400-425 for 1 hour
XVI	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1/2 of heat- ing time	Brine or Water	400 for 1 to 2 hours
XVII	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1/2 of heat- ing time	Brine	400 for 1 hour
XVIII	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1/2 of heat- ing time	Oil	350 for 1 hour
XIX	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1/2 of heat- ing time	Brine or Water	350 for 1 hour
XX	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1/2 of heat- ing time	Water	400 for 1 hour
XXI	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time			1 hour per in. of dia. or thick- ness	1/2 of heat- ing time	Water or Oil	400-450 for 1-2 hours
XXII	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time	1550- 1600	Air	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time	1325- 1375	35	1 hour per in. of dia. or thick- ness	1/2 of heat- ing time	Water at 120 deg. F.	450-525 for 1 hour
XXIII	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time	1475- 1525	Air	1 hour per in. of dia. or thick- ness	1 hour per 1/2 of heat- ing time	1375- 1400	35	1 hour per in. of dia. or thick- ness	1/2 of heat- ing time	Oil	450-700

*When hardening, pack all dies in suitable carbonaceous material or place face down in a pan of carbonaceous material.

is between the annealing and normalizing temperatures. When the temperature has been reached and held for a sufficient time, the door of the furnace is opened and the die blocks allowed to cool down with the aid of air. This operation cannot be called either annealing or normalizing, but it puts the die blocks in a good soft condition. As it is often necessary to squeeze the die blocks several times before the impression is fully up from the master hob, this heat treatment is performed upon the die blocks between each squeeze.

Hardening—The die blocks are pack hardened in suitable carbonaceous material to prevent scale forming in the fine intricate patterns. Great care is employed in bringing the dies up slowly to the proper hardening temperature and great care is also exercised in the quenching operation.

Table VIII gives the hardening temperature, and it will be noticed that these temperatures are well above the critical range. These high temperatures are most desirable in the case of shock dies and it has been proved by repeated experiments that the production has increased greatly.

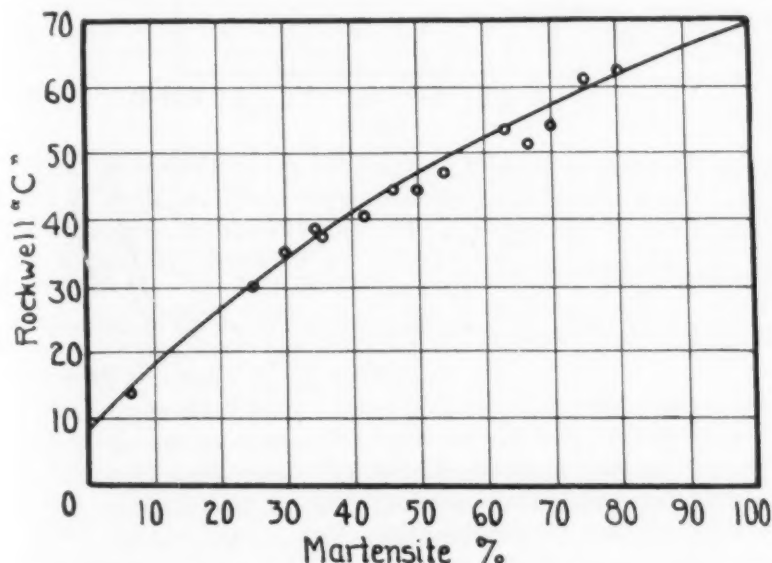
Tempering—After quenching, the die blocks are tempered immediately at the temperature given in Table VIII. A minimum Brinell hardness number of 555 is suggested, depending on the kind of metal to be struck and the pattern.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

ON THE HARDNESS OF DIFFERENT STRUCTURES OF STEELS.
By Kanji Tamaru. *Kinzoku no Kenku*. Vol. 3, No. 6, 1926, p. 299-316.

The hardness of different structures of steels is not yet accurately known, especially those of austenite and cementite. For the determination of the hardness of martensite and austenite, the author used a high carbon steel containing 1.69 per cent carbon, and quenched the specimens from 1120 degrees Cent. into three different media—calcium chloride solution cooled to -15 degrees



Cent, the same solution at 20 degrees Cent, water at 20 degrees Cent—to obtain structures containing different amounts of martensite. These specimens were then polished, etched with acid and photographed at 400 magnification; the area of the martensite was then measured by a planimeter, and its hardness by a Rockwell tester. The structure consisted solely of martensite and austenite. The curve of the hardness plotted against the area of the martensite or the austenite is given in the Fig. By the extrapolation of the curve on both sides, the author obtained the following numbers:—

The hardness of martensite = 68.5 Rockwell hardness = 720 Brinell hardness.

The hardness of austenite = 9.0 Rockwell hardness = 155 Brinell hardness.

The author also determined the hardness of austenite by using austenitic steels containing varying amounts of manganese from 10 to 22 per cent and carbon from 0.2 to 0.9 per cent. The hardness of these steels was almost independent of manganese content, but slightly decreases with the increasing con-

tent of carbon. By extrapolating the hardnesses of these steels to the concentration of 1.69 per cent of carbon, the author obtained 156 Brinell hardness, which value agrees satisfactorily with above value.

For the determination of the hardness of cementite, specimens of steel and cast iron containing different amounts of carbon from 1 to 5.55 per cent were prepared. In the case of high carbon cast iron, a melt consisting of a mixture of iron and carbon was poured into a thick copper mold having a hole of

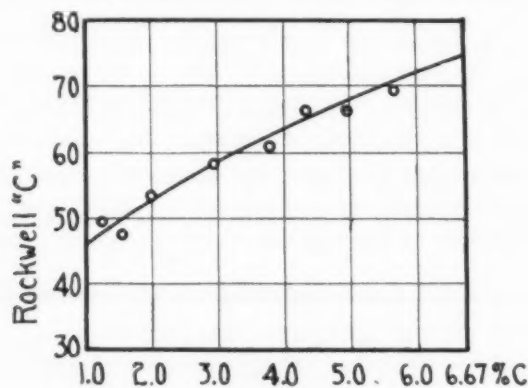


Fig. 2.

rectangular flat section, in order to avoid the graphitization of the precipitated cementite. The results of the hardness measurement are given in the Fig. By the extrapolation of the curve to the concentration of cementite, the author obtained for the hardness of cementite 74 Rockwell hardness or 820 Brinell hardness.

The following table contains the authors' result of measurements:—

	Brinell Hardness
Armco iron	90
Austenite	155
0.9 per cent Normalized steel	225
0.9 per cent Sorbitic steel	270
0.9 per cent Troostitic steel	400
1.6 per cent Martensitic steel	720
Cementite	820

Above 0.8 per cent carbon, the hardness of the martensitic steel does not sensibly increase with carbon content. *Abstracted by Dr. Kotaro Honda.*

THE HIGH FREQUENCY INDUCTION FURNACE. By F. Wever, Duesseldorf. *Stahl und Eisen*, April 22, 1926, p. 533-536.

The author gives an explanation of the principles of this furnace and describes the high frequency melting plant of the Kaiser Wilhelm Institut für Eisenforschung with sets of machines from 8 and 30 KVA. In this plant the high frequency machine, developed by the Lorenz, A.-G., Berlin-Tempelhof, is used.

The advantages of the high frequency induction furnace are: favorable furnace efficiency, small requirement of the furnace lining, the absence of carbon electrodes and by this of a carbonizing atmosphere, great speed of re-

action owing to the whirling of the bath by arising electromechanical forces; furthermore there is the possibility of melting in any oxidizing, reducing or neutral atmosphere.

This preferences of the high frequency furnace show clearly, that the final development of this process may be qualified as one of the most urgent questions of electro-metallurgy. *Abstracted by Dr. Hans Pollack, Germany.*

THE DIFFUSION OF CARBON IN ALPHA IRON. By E. Zingg, Vallorbe (Switzerland). Report from the Eisenhüttenmännischen Institut der Technischen Hochschule Aachen. *Stahl und Eisen*, June 10, 1926, p. 776-777.

The purpose of this investigation is the clearing-up of the question whether carburizing takes really place below the A_{c_3} respectively the A_{c_2} point. As carburizing material a mixture consisting of hydrogen, carbohydrates and carbon monoxide was used. The heats were carried out in a chromium-nickel wire furnace with porcelain tube. The temperature at the first experiment was continually decreasing with a maximum from 780 to 800 degrees Cent. (1436 to 1472 degrees Fahr.), that of the second one was constant and amounted 670 to 690 degrees Cent. (1238 to 1274 degrees Fahr.). The duration of the first experiment was 20 hours, that of the second one 60 hours. After finishing the experiments the porcelain tube was taken out of the furnace with the sample and the latter was cooled on the air without intermission of the gas-current.

The carburizing samples consisted of:

(1) Swedish cold-rolled weld iron, recrystallized in a current of hydrogen at 600 degrees Cent. (1112 degrees Fahr.) from 60 x 10 x 0, millimeters.

(2) Rolled Steel of 1.20 per cent carbon, 0.23 per cent silicon and 0.27 per cent manganese. The measurements of the sample were the same as above; the structure of this steel consisted of sorbite and cementite.

The second experiment was carried out with weld iron, treated as above; the thickness of it amounted 0.5 millimeter.

The microscopic examination showed that the border zone of the samples in the temperature range from 650 to 800 degrees Cent. (1202 to 1472 degrees Fahr.) consisted of cementite. The second experiment showed that thin steel sheets become transformed almost without a remainder into cementite in the range from 670 to 690 degrees Cent. (1238 to 1274 degrees Fahr.) if the action is long enough.

The present results verify those of Fry, who differentiates between true diffusion and reacting diffusion. The true diffusion takes only place to the content of the saturated solid solution while at the reacting diffusion the content of the highest chemical composition may be attained.

Abstracted by Dr. Hans Pollack, Germany.

ON A NEW ALLOTROPY OF COBALT. By Hakar Masumoto. *Kinzoku no Kenku*. Vol. 2, No. 9, 1925, p. 877-893.

Hitherto it has been believed that cobalt possesses only the magnetic transformation at 1150 degrees Cent. and has no other transformation; but from the investigation for the change of several properties of cobalt at high temperatures, such as, the intensity of magnetization, the electric resistance, the thermal expansion, the specific heat, etc., the present author concluded that

cobalt has a new transformation or an allotropy taking place at 477 and 403 degrees Cent. during the heating and cooling respectively. Figs. 1 and 2 are respectively the electric resistance-temperature curve and the thermal expansion-temperature curve; Fig. 3 is the magnetization-temperature curve. It was also

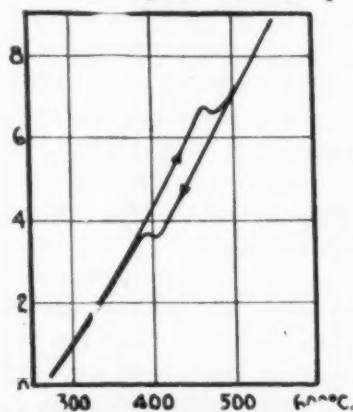


Fig. 1—Electric Resistance—Temperature Curve.

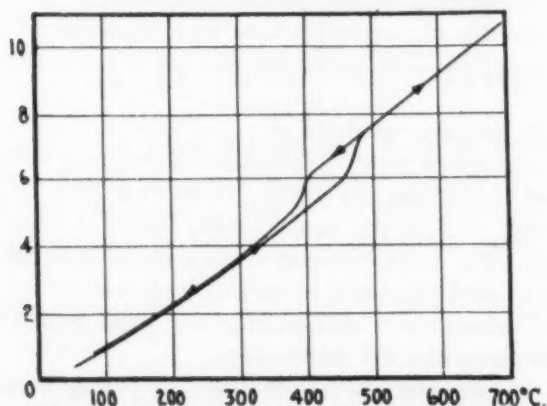


Fig. 2—Thermal Expansion—Temperature Curve.

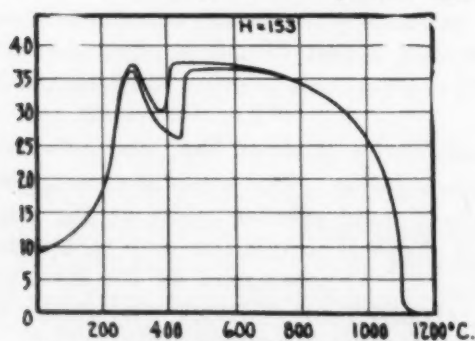


Fig. 3—Magnetization—Temperature Curve.

confirmed by X-Ray analysis that below the transformation point, cobalt has a hexagonal closed-packed lattice (H) and above it a face-centred lattice (gamma); hence the new transformation during heating consists of the change from H-lattice to gamma-lattice, and the transformation during cooling, of the change from gamma-lattice to H-lattice. The peculiar course of the magnetiza-

at 477 and 403
gs. 1 and 2 are
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curve. It was also

tion-temperature curve below 400 degrees Cent. is due to the magnetic transformation of the hexagonal cobalt, and the abrupt rise at 477 degrees Cent. and the abrupt fall at 403 are due to the change of the intensity of magnetization during the transformation. The diminution of magnetization at higher temperatures is due to the magnetic transformation of the face-centered cobalt.

Abstracted by Dr. Kotaro Honda.

RESEARCHES ABOUT THE THERMAL CONDUCTIVITY OF REFRACTORY MATERIALS. By Dr.-phil. A. Kanz, Dortmund. *Transactions of the Material-Committee of the Verein deutscher Eisenhüttenleute.*

This is a summary over the corresponding literature up to January 1, 1926.

The investigations about the thermal conductivity of refractory materials after the different methods, having been known hitherto, are described: where it was possible, numerical values are given; their reliability is carefully considered.

Though a great number of numerical values about the thermal conductivity of refractory materials exists, our informations are still imperfect; the results of the single investigators are partly contradictory in such a manner, that a systematic verification of the values seems urgently desirable.

Abstracted by Dr. Hans Pollack, Germany.

WORKING METHOD OF ELECTRIC ARC FURNACES. By E. Riecke, Berlin. *Transactions, Steel Works Committee of the Verein deutscher Eisenhüttenleute.*

In this paper the author described the relations between the electric arc voltage and the electric arc energy, the factor of effect and the efficiency if a certain number of K V A is supplied to the transformer at a certain idle run voltage of the electrodes and it is showed what conclusions may be drawn from these relations for the practical working.

Abstracted by Dr. Hans Pollack, Germany.

ON THE EQUILIBRIUM DIAGRAMS OF COBALT-NICKEL AND COBALT-IRON. By Hakar Masumoto. *Kinzoku no Kenku.* Vol. 2, No. 10, 1926, p. 1023-1038.

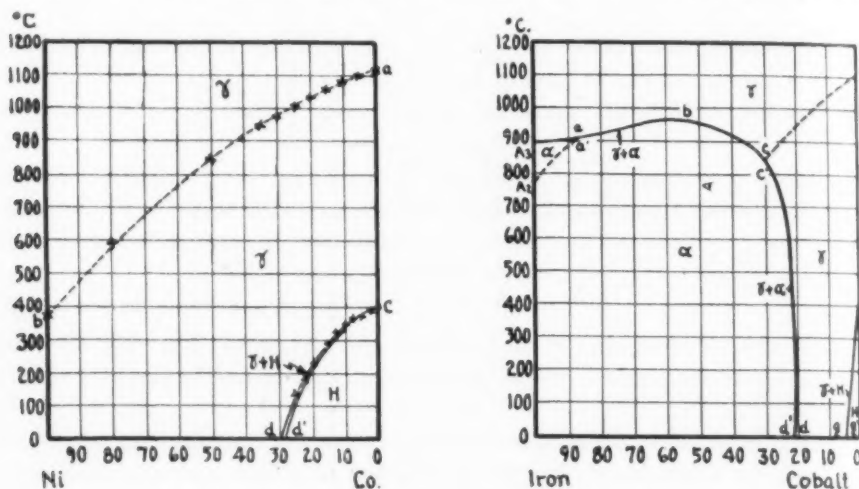
Since a new allotropy of cobalt has been found, it was necessary to revise the equilibrium diagrams of cobalt-iron and cobalt-nickel. The author newly investigated the whole system of these alloys by means of magnetic analysis, electric resistance, thermal expansion, thermal analysis, microscopic investigation, and X-ray analysis; the equilibrium diagram of these systems of alloys are given in Figs. 1 and 2.

Nickel has a magnetic transformation, which is not any change of phase, but no allotropy; cobalt has a magnetic transformation and an allotropic change at high temperature. As shown in Fig. 1, the temperature of the allotropy of cobalt at 403 degrees Cent. is lowered by adding nickel to cobalt and falls below the room temperature at 29 per cent of nickel (line *cd. cd'*). The magnetic transformation point of cobalt decreases gradually, as nickel is added to cobalt, down to that of pure nickel, as shown by line *ab*. As this transformation is not any change of phase, the line *ab* is drawn by a dotted line to distinguish this transformation from the line representing the change of phase.

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From the same figure, it is to be concluded that at room temperature, alloys containing greater than 30 per cent of nickel must have all lattice and those containing less than about 25 per cent of nickel have H-lattice, the alloys lying between these two per cents consisting of a mixture of gamma and H-lattices. This conclusion agrees with the result of X-ray analysis.

Iron possesses a magnetic transformation (A_2) and an allotropic change (A_3); the A_2 point of pure iron slightly increases with the addition of cobalt to iron, and after passing through a maximum at 45 per cent of cobalt, rapidly decreases and at 80 per cent of cobalt, already falls below the room temperature (line A_3 $abcd$). The allotropic point of cobalt is lowered very rapidly by add-



ing iron to cobalt and falls below the room temperature at 5 per cent of iron (line fg , fg'). The A_2 point of iron rises rapidly at first and coincides with the A_2 line at 13 per cent of cobalt (dotted line A_2a'). The A_2 point of cobalt is lowered by adding iron to cobalt and coincides with the A_2 line at 28 per cent of iron (dotted line ec).

It is to be concluded that at room temperature, alloys containing greater than 23 per cent of iron must have an alpha-lattice, those containing 5-20 per cent of iron have a mixture of gamma and H-lattice, and those containing less than 3 per cent of iron consist of H-lattice. There must also be a narrow heterogeneous range just below 5 per cent and that just above 20 per cent, of iron, consisting of a mixture of H + gamma and that of alpha + gamma, respectively. The result of the X-ray analysis agrees satisfactorily with the above conclusions.

Abstracted by Dr. Kotaro Honda.

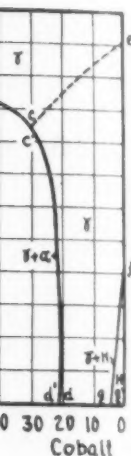
MEASUREMENT OF THE POROSITY OF COKE, REFRACTORY MATERIALS AND STAMPED MOULDING SANDS. By H. Esser and E. Piwowarsky. Report of the Eisenhuettenmännischen Institut der Technischen Hochschule Aachen. *Stahl und Eisen*, April 29, 1926, p. 565-567.

This paper deals with a method for the determination of the porosity and of the true and apparent specific gravity of coke, refractory materials and dry molding sands.

The method is founded on the following idea:

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If the quantity of air, being in a vessel for taking up the samples, is rarefied for a certain degree by sucking off in a burette and if the same procedure is repeated after the taking up of the sample, then gives the difference of the two tests, read off on the burette and multiplied with the quotient height of the barometer, the true volume of the tested material cm^3 . The rarefaction-pressure

apparent volume determined in the same apparatus by the quick-silver removal method makes the appointment by calculation possible.

The construction of the new apparatus, the adjustment and the performance of the measurement are detailed described.

Abstracted by Dr. Hans Pollack, Germany.

THE INFLUENCE OF THE THICKNESS OF INGOT MOLDS ON THE INGOT. By Dr.-Ing. F. Leitner, Kapfenberg. *Stahl und Eisen*, May 13, 1926, p. 629-631.

This paper deals with the problem, to clear up the influence of the thickness of wall on smaller ingot sections. It is divided into two parts: the appointment of the upper bound of the thickness by exceeding of which the solidification is no more influenced and the examination of the phenomena taking place if the thickness of the ingot-mold decreases.

The points of view, being of some account for this, are: the primary crystallization, the speed of solidification, the durability of the ingot molds and their heating.

Ingots of 140 and 230 millimeters in diameter and of 250 millimeters in square were used. The formation of crystallites was examined on a soft chromium-nickel steel, the speed of solidification on a high carbon, high manganese steel. For the microscopic examination transverse tests were taken from the middle of the ingot. The progressing solidification was determined by overturning the ingot molds after teeming and measuring of the solidified surface zone.

The thickness of the ingot molds was: 55, 45, 40, 30 and 25 millimeters for the 140-millimeters ingot, 65, 55, 45, 35 and 30 millimeters for the 230-millimeters ingot and 75, 65, 55, 45 and 35 millimeters for the 250-millimeter ingot. The pouring temperature of the chromium-nickel steel was about 1650 degrees Cent. (3002 degrees Fahr.); the ingots were top-poured with a pouring velocity of 0.6 meters per minute.

Pouring ingots of 140 millimeters in diameter, the most favorable results were obtained with ingot molds of 30-35 millimeters thickness and pouring such of 230 and 250 millimeters, ingot molds of 35-40 millimeters may be used.

A retardation of the solidification time by using the thin ingot molds could not be stated. Till now differences in the durability of the ingot molds from different thickness could not be observed. The heating of the ingot molds after pouring attained in no case a temperature of 750 degrees Cent. (1382 degrees Fahr.). Thin ingot molds have the preference that the ingot-core consists of fine crystals, which are most favorable in regard of the distribution of impurities and crystal segregations.

Abstracted by Dr. Hans Pollack, Germany.

METALLOGRAPHIC DETERMINATION OF PHOSPHORUS. By Dr. Ing. Haufe; Kruppsche Monatshefte, April, 1926, p. 66-69.

This is a study of the preferences and disadvantages and above all of the sensitiveness of different etching reagents on phosphorus. The reagents were tested on a piece of Thomas-made steel with 0.04 per cent carbon, 0.46 per cent manganese, 0.070 per cent phosphorus, 0.041 per cent sulphur and traces of silicon, and had the following chemical composition:

	Heyn	Stead	Rosenhain	Le Chatelier		Oberhoffer	Fry		
				1	2		1	2	3
Water H_2O	100	1000	1000	180	10	500	95	40	30
Hydrochloric acid HCl ..	20	100	100	20	1.5-2.5	50	30	20	40
Cupric chloride $CuCl_2$..	10	1	1	..	..	1	1.5	4	5
Ferric chloride $FeCl_3$ ..	..	30	30	..	..	30	..	..	..
Magnesium chloride $MgCl_2$..	40	..	..	40	..	..	..	..	..
Cupric chloride Cu_2Cl_2 ..	..	..	..	10	1	..	..	..	..
Stannous chloride $SnCl_2$ ..	..	..	0.5	..	..	0.5	..	..	..
Copperammonium chloride	12	..	..	..	..	..	..	..	..
Methyl alcohol CH_3OH ..	..	..	..	1000	..	..	..	..	..
Ethyl alcohol C_2H_5OH ..	..	..	..	..	100	500	30	20	25
Picric acid .....	..	..	..	..	0.5	..	..	..	..

The numbers mean grams and cubic centimeters.

Further, hydrochloric acid in alcohol and ammonium-persulphate + ferric chloride were used.

Using the reagent, proposed by Heyn, the whole specimen is covered by a spongy copper coating, but this latter does not prevent further attack of the segregations; in opposition to that a copper film, protecting the segregations, is deposited by etching with the other solutions.

The results of the study are:

- (1) Hydrochloric acid in alcohol (1:1) is unfit for the use as phosphorus etching reagent.
- (2) The solutions of Heyn, Oberhoffer and Fry 2 give very satisfactory results, above all the first may be generally used.
- (3) The reagents of Rosenhain and Le Chatelier are useful, but difficult to handle.
- (4) Stead's solution is unavailable because all finenesses of detail are lost.
- (5) For microscopical etching the solution 1 of Fry is used.
- (6) The solution 3 of Fry and ferric chloride are strong reagents and the finenesses are difficult to recognize.

Abstracted by Dr. Hans Pollack, Germany.

Reviews of Recent Patents

By

NELSON LITTELL, Patent Attorney

475 Fifth Ave., New York City

Member of A. S. S. T.

1,592,181, Production of Low-Carbon Steel for Structural and Similar Purposes, Welton J. Crook, of Stanford University, California, Assignor to Pacific Coast Steel Company, of San Francisco, California, a Corporation of California.

This patent describes a process of producing low carbon steel for structural purposes, having higher elastic limits than that usually provided. The process comprises heating normal steel containing not over 0.25 per cent carbon and between 0.5 and 1 per cent manganese, to a temperature of 1300 to 1700 degrees Fahr., holding this temperature from ten minutes to one hour, quenching rapidly and reheating to a temperature not above 1300 degrees Fahr., retaining this temperature for a period of ten minutes to one hour or longer and thereafter cooling the same.

1,592,302, Heat Treating Magnesium Alloy, Zay Jeffries and Robert S. Archer, of Cleveland, Ohio, Assignors to American Magnesium Corporation, of Niagara Falls, New York, a Corporation of New York.

This patent describes a method of heat treating magnesium alloys and secures the most desirable results with a magnesium alloy containing 12 per cent of aluminum. The alloy is first given a heat treatment of 400 to 440 degrees Cent. to secure a solid solution of magnesium and aluminum which will be super-saturated at room temperature and thereafter subjected to a heat treatment of 125 to 300 degrees Cent. for a period of time sufficient to cause precipitation of the hard constituents; preferably the first treatment is continued for approximately one half hour, the piece is then quenched and reheated to a lower temperature for approximately fifteen hours.

1,592,659, Machine for Heat Treating Metallic Bodies, George H. Gilman, of Claremont, New Hampshire.

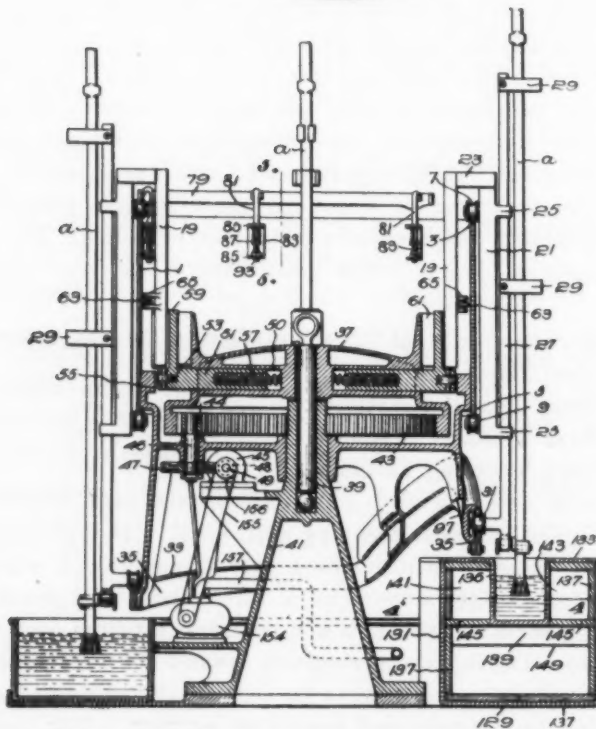
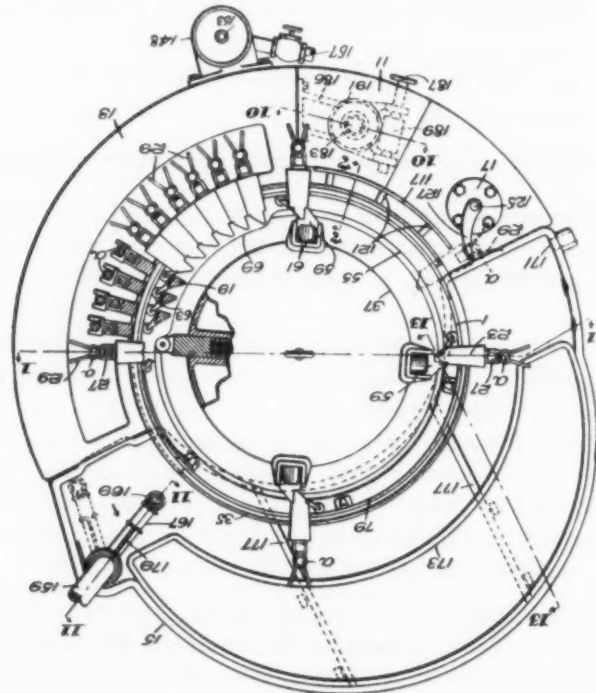
1,592,660, Heat Treating Articles.

1,592,661, Heat Treating Machine.

1,592,662, Heat Treating Machine.

These patents describe and claim automatic heat treating machines, particularly designed for heat treating drill steel, although capable of other uses. The above patents all describe a turret machine in which the pieces undergoing treatment are moved in a circle past the loading platform, through a heating medium, through a quenching medium and then removed from the machine. During the movement around the turret, the pieces may be given an up and down movement to control the rate and degree of the quenching, as well as the rate and degree of heating. The patents describe various refinements in the driving mechanism, the means for gripping the

drill steel pieces and holding them in their movement around the turret, means for releasing the same, and improvement in construction of the



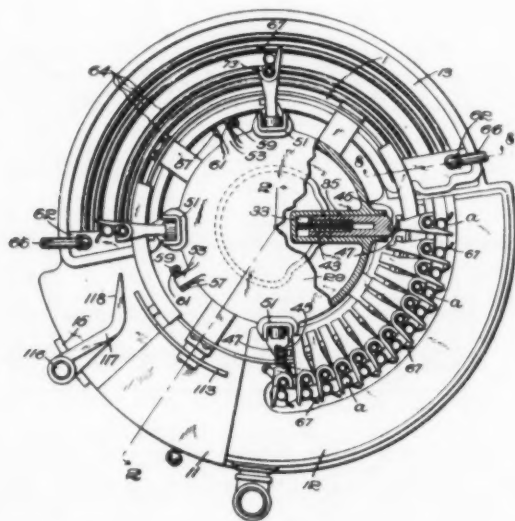
heating and quenching chambers, as well as details of the way the pieces are moved into or out of the chambers. A typical view of the construction

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shown and described is illustrated in Figs. 1 and 2 of the patent No. 1,592,661 printed herewith. In this construction, the machine comprises a rotating turret 37 provided with radial arms carrying suitable clamps 29 for holding the drill rods *a*, a motor 154 rotates the turret through the medium of the worm wheel 47 and spur gear 44. The rods 27 holding the clamps 29 are slidably secured in arm 25, and the roller 31 secured to the rods 27 and running on a cam track 35 and cam 97 controls the raising and lowering of the rods as they travel around the turret. The heating medium comprises a lead pot 135 and the quenching medium comprises the tank 15. In Fig. 2, 11 indicates the loading platform at which the drill rods are placed in the clamps 29; 13 indicates the heating chamber and 15 the quenching tank. The inlet nozzle for cold water is indicated at 169 at the entrance to the quenching tank, so that the heated drill rods emerging from the heating chamber 13 are immediately subjected to a blast of cold water to give a high degree of hardness to the tip of the drill rod. 173 indicates a second tank adapted to contain oil if it is desired to use oil for the quenching fluid in lieu of water. 17 designates the mechanism for automatically disengaging the drill steel from the carriers so as to permit the same to be reloaded when they come opposite the loading platform 11.

1,593,950, Heat Treating Machine, John Albert Pierson, of Melrose Highlands, Massachusetts, Assignor to George H. Gilman, of Belmont, Massachusetts.

This patent describes a turret type heat treating machine, also designed for treating drill rods or the like, and which is constructed in such



a way as to have relative variations in movement between the propeller and the carriage, and controlled so that the propeller runs in advance of the carriers, while the latter are in the heating chamber and the carriers advance faster than the propellers, when the carriers move from the heating chamber toward the cooling chamber so as to vary the rate of travel

way the pieces
the construction

of the carriers around the turret. Fig. 1 is a plan view of the construction of the machine.

1,593,924, Alloy Steel, Roy T. Wirth, of East Cleveland, Ohio.

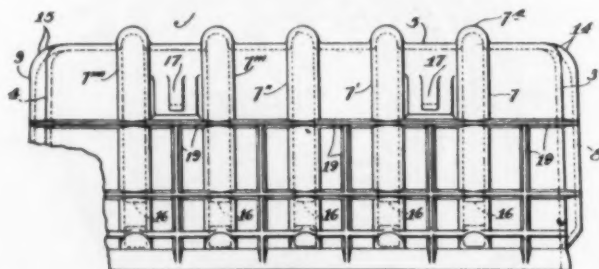
This patent describes an alloy composition capable of being varied within wide limits designed to produce an alloy suitable for a cutting tool. The alloy comprises preferably carbon, iron, from 2 to 30 per cent of chromium, not less than 10 per cent of tungsten and molybdenum sufficient to make a total percentage of chromium, tungsten and molybdenum in excess of 35 per cent.

1,592,996, Alloy, Harold G. Weidenthal, of Cleveland, Ohio, Assignor to the James H. Herron Company, of Cleveland, Ohio, a Corporation of Ohio.

This patent describes an alloy particularly intended for use in making die blocks and tools for working hot metal. The alloy is preferably made by adding to steel of the proper carbon content a predetermined amount of silicon together with the proper proportions of chromium and a suitable scavenging agent such as uranium, vanadium, molybdenum or the like. A specimen composition of the alloy comprises chromium, 3 to 6 per cent, silicon 1 to 2½ per cent, carbon, 0.30 to 1.00 per cent, uranium (or equivalent) 0.10 to 0.30 per cent, phosphorous, sulphur, manganese as in normal steel specifications and iron by difference to make 100 per cent.

1,592,852, Plate-Annealing Hood, Gustav A. Hassel, of McKeesport, Pennsylvania, Assignor to Pittsburgh Steel Foundry Corporation, of Glassport, Pennsylvania, a Corporation of Pennsylvania.

This patent describes an annealing box or hood of the usual rectangular shape, having a plurality of corrugations 7 extending over the top and sides thereof. The novelty of the particular box comprises providing the



top or crest of corrugations with more metal to increase the thickness thereof and providing bridge walls 16 extending from side to side of the corrugations to reenforce and strengthen the same. 19 indicates external strengthening ribs extending between the corrugations.

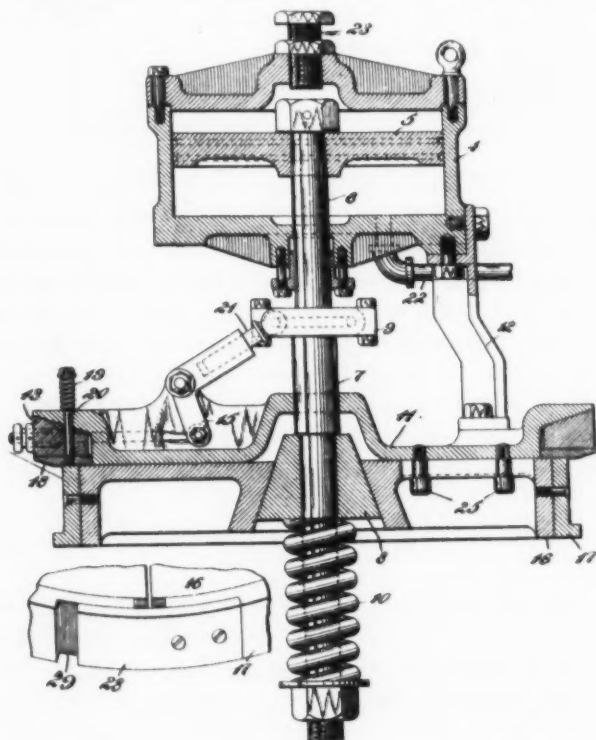
1,594,133, Process of Treating Ingot Iron, Wilhelm Tafel, of Breslau, Germany.

This patent describes the process for a treatment of ingot iron with a finishing welding slag capable of dissolving out the ferric and ferrous

oxides, producing a deoxidized material similar to wrought or weld iron. The process comprises adding to the molten ingot iron in furnace a mixture or slag containing ferric oxide, ferrous oxide and silica substantially as described to effect proper refining of the ingot iron.

1,595,725, Gear-Rim Holder, William H. Phillips, of Aspinwall, Pennsylvania, Assignor to R. D. Nuttall Company, a Corporation of Pennsylvania.

This patent describes an apparatus for holding gear rims to prevent distortion while undergoing heat treatment of same, particularly during the quenching operation. The apparatus comprises a holder 4 designed to be suspended from a crane; in use the gear rims are removed from the furnace, the holder placed on the inside of the same and fluid pressure admitted to the cylinder 4 through the pipe 22, to draw the wedge 8

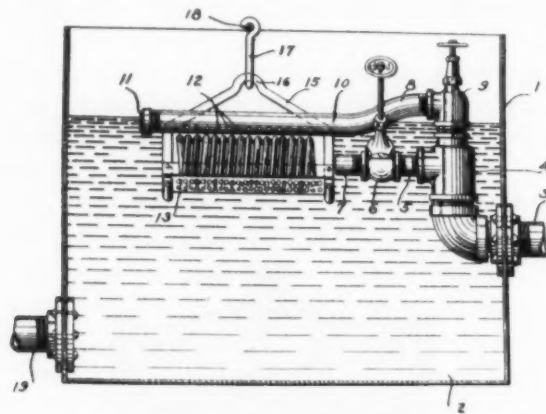


against the clamps 16, causing the same to expand into firm contact with the inner edge of the gear rim; at the same time the bell cranks 15 draw the wedges 13 inwardly, forcing the member 18 against the top of the gear rim, while the lower portion of the gear rim rests upon the shoulders of the portions 17. While tightly held in this position the gear rim is placed in the quenching fluid and cooled without uneven shrinkage or distortion.

1,595,803, Helical-Spring-Quenching Device, William J. Merten, of Pittsburgh, Pennsylvania, Assignor to Westinghouse Electric & Manufacturing Company, a Corporation of Pennsylvania.

This patent describes an apparatus for uniform quenching of helical

springs. Difficulty has heretofore been experienced in obtaining a uniform quenching of helical springs because of the tendency of the quenching fluid to form gas pockets on the inside of the spring, retarding the circulation of the quenching fluid and producing a harder outer than inner surface. The present invention comprises suspending the spring in the



quenching medium 2 by means of a perforated cradle 13 secured by means of handle 15 and hook 17 to the top of the quenching tank. Pipe 10 having perforations 12 is designed to spray the oil or other quenching fluid under pressure over the spring in the quenching bath 2, and a nozzle 7 controlled by a valve 6 forces a spray of the quenching fluid under pressure through the interior of the coiled spring to provide for uniform cooling of all portions thereof.

The Question Box

A Column Devoted to the Asking, Answering and Discussing
of Practical Questions in Heat Treatment — Members
Submitting Answers and Discussions Are Requested
To Refer to Serial Numbers of Questions

QUESTION NO. 191. *Is there any available data on the temperature curve for breaking up the double carbides in an electric furnace steel having an approximate chemical analysis of 0.40% carbon, 1.00% chromium, 2.50% nickel and 0.80% manganese?*

QUESTION NO. 190. *What is the most suitable thickness of a copper plate coating to prevent carburization in the box type method of carburizing?*

QUESTION NO. 189. *What is the McQuaid-Ehn test and what are its merits in selecting steel for carburizing?*

QUESTION NO. 188. *What causes the scaling on the inside of holes of piston pins when heated in a Hoskins electric pusher type furnace? Does the sulphur content of the steel have any marked effect?*

QUESTION NO. 187. *What causes the carbonaceous deposit on steel parts when quenched in oil from temperatures about 1600 degrees Fahr.? How can this be eliminated? Do all oils have the same effect in the same degree?*

ANSWER. By S. P. Rockwell, Hartford, Conn. Believe that the carbonaceous deposit referred to is due to the oil breaking down and depositing solid carbon on the steel. It has been the writer's experience that this can occur at lower temperatures. Certain oils have this disagreeable feature attached to them more than others.

QUESTION NO. 186. *Why should marking dies be rubbed with emery cloth before using?*

QUESTION NO. 185. *What precaution should be observed in designing such a tool?*

QUESTION NO. 183. *What effect, if any, have the additions of alloys on the internal stress of tool steels?*

QUESTION NO. 180. *Explain the effect of decarburization in grinding.*

QUESTION NO. 179. *What is the difference between grinding cracks and grinding checks?*

QUESTION NO. 171. *What is the hardness of carbon steels at elevated temperatures such as 400 to 1000 degrees?*

QUESTION NO. 169. *What is the hardness of high speed steel at elevated temperatures such as 400 to 1000 degrees?*

QUESTION NO. 165. *What importance should be placed on the carbon content of high speed steel?*

QUESTION NO. 158. *What is the present recognized cause for the "transverse fissure" as occasionally found in rails?*

ANSWER. By C. G. Williams, mechanical engineer, Sunstrand Engineering Co., Rockford, Ill.

Information recently given out by the Government lays the cause of the

"Transverse Fissure" almost entirely to the heavy wheel loads of locomotives and cars in conjunction with dense traffic, but also state:—"There are minor causes such as slag inclusions in the interior of the steel and seamy lines inherent in all steels."

In a study of steel rails, carried on from 1919 to 1925, the writer found transverse fissures in rails that had been in use on branch lines for years and also in main line rails that had not been in use over two years, and in one case, on a line that did not have the heaviest of power. In fact, the power then in use on that line had been sent in as being relieved from other parts of the system by the installation of some of the heaviest of units.

Some of these fissures were, undeniably, the results of inclusions, others were the results of seamy lines occasioned by the rolling out of gas pockets formed in the ingot. At least two cases could be laid entirely to rough usage, for at those two points were the imprints made by the spinning drivers when slipping. The sudden heating up of the surface of the steel by the friction of the spinning drivers causing expansion and the sudden contraction after this expansion caused surface cracks in the head of the rail that ultimately lead to transverse fissures.

The statement that:—"Evidence leads in one direction only, that is, that responsibility rests on the overwork to which the rails are subjected" and "Diligent research has not attached responsibility for the formation of transverse fissures to mill conditions", should not be considered as entirely absolving both the railroads and the steel mills. It is true that of the two, the railroad officials should bear the greater load of responsibility, as they have asked for steels of certain specifications, but in most cases these specifications have been recommended by the steel men.

For years the trend had been toward high carbon steels and extra hard rails. For a long time the writer had been of the opinion that a lower content of carbon and a much higher content of manganese and possibly a higher content of silicon would give a steel rail that would give far better results with the sections now in use. About two years ago the high official of one road was approached on this subject which was terminated quickly by the statement that "the specifications we are now presenting to the steel mills have been highly recommended by the mills themselves as being those that will give the best results." Answering the question, what is the content of manganese, he stated:—"We want only a low content of manganese as we are informed that brittleness and other injurious effects come from its use."

However, it is held that present steels are so far from satisfactory that new specifications must soon be evolved, and from test specimen, the writer would suggest, not over 0.45 per cent carbon; 2.25 to 2.40 per cent manganese; 0.75 per cent silicon; 0.02 per cent phosphorus and 0.015 per cent sulphur. It is believed that the addition of copper up to 0.25 per cent would give good results. This steel would need to be heat treated to bring out its best qualities, but heat treatment will give a high ductility (up to 28 per cent) and it is held that the steels with less than 6 per cent elongation, as used at present, are entirely too hard and brittle and conducive to the formation of transverse fissures under present wheel loadings.

News of the Chapters

STANDING OF THE CHAPTERS

IN the August issue of TRANSACTIONS appeared the relative membership standing of the 29 chapters of the Society as of June 1, 1926, and as of July 1, 1926. The tabulation which appears below shows the relative membership standing of the chapters on July 1, 1926, and August 1, 1926.

STANDING OF THE CHAPTERS AS OF AUGUST 1, 1926

GROUP I	GROUP II	GROUP III
1. Cleveland .....375	1. Lehigh Valley ..141	1. Los Angeles .....74
2. Detroit .....364	2. Hartford .....135	2. Tri-City .....64
3. Philadelphia ....360	3. Golden Gate ...125	3. Rockford .....61
4. Chicago .....326	4. Milwaukee .....100	4. Washington .....61
5. Pittsburgh .....310	5. Syracuse 98	5. New Haven 56
6. New York .....256	6. Cincinnati 85	6. Worcester .....55
7. Boston .....236	7. Indianapolis 82	7. Montreal .....54
	8. St. Louis 73	8. Rochester .....53
	9. Buffalo 57	9. Schenectady ....48
	10. North West 48	10. Toronto .....46
		11. Providence .....41
		12. Fort Wayne ....33
		13. Springfield .....29

STANDING OF THE CHAPTERS AS OF JULY 1, 1926

GROUP I	GROUP II	GROUP III
1. Detroit .....(380)	1. Lehigh Valley ..(140)	1. Los Angeles ... (72)
2. Cleveland .....(374)	2. Hartford .....(135)	2. Tri City .....(65)
3. Philadelphia ... (356)	3. Golden Gate ..(129)	3. Rockford .....(62)
4. Chicago .....(319)	4. Syracuse .....(100)	4. Washington ... (62)
5. Pittsburgh .....(318)	5. Milwaukee .....(99)	5. New Haven ....(58)
6. New York .....(260)	6. Cincinnati .....(85)	6. Worcester .....(56)
7. Boston .....(238)	7. Indianapolis ... (84)	7. Rochester .....(54)
	8. St. Louis .....(76)	8. Schenectady ... (48)
	9. Buffalo .....(57)	9. Montreal .....(48)
	10. North-West ....(48)	10. Toronto .....(47)
		11. Rhode Island... (43)
		12. Fort Wayne ... (33)
		13. Springfield ....(30)

There were 55 new and reinstated members for the month of July, while 69 were dropped for non-payment of dues and there were 16 resignations and deaths, leaving a net loss for the month of 30 members. The total membership of the Society at the present time is 3,997. Those members dropped for

non-payment of dues held membership expiring in April and were carried from that time until it was necessary to drop them due to the A. S. S. T. Constitution as well as postal regulations.

GROUP I—Detroit suffered a net loss last month of 16 members, which pulled them out of first place and permitted Cleveland, having a gain of one member, to occupy position 1, with a lead of 9. Philadelphia, Chicago and New York showed slight gains, while Pittsburgh and Boston showed losses.

GROUP II—Lehigh Valley continues to head this group with a lead of 6 members over Hartford. Milwaukee and Syracuse exchange places this month, Milwaukee again coming back into the "100" class and Syracuse dropping a little below. The remaining chapters in this group hold the same positions as on the last report.

GROUP III—Los Angeles increased its lead over Tri City to 10 members. Rockford and Washington still hold the tie as shown in the June report. New Haven and Worcester are still in positions 5 and 6, while Montreal, the new baby of the lot, advanced from 9th to 7th position, with a total of 54 members, displacing both Rochester and Schenectady. Toronto, Providence, Fort Wayne and Springfield still hold their same positions.

BOSTON CHAPTER

Advance notice of the seventh annual outing of the Boston Chapter to be held at Red Hill Country Club, North Reading, Massachusetts, Saturday, September 11, 1926, at 2:00 p. m., has just reached us.

The tentative program for 1926-27 schedules interesting plant visitations and talks by men who are authorities on various subjects each month from October to May inclusive.

GOLDEN GATE CHAPTER

The June meeting of the Golden Gate Chapter, American Society for Steel Treating, was held at the Engineer's Club on June 9, there being 57 members in attendance.

Forty-five attended the dinner preceding the meeting. There were two speakers of the evening: R. T. Wise, manager of the Standard Die and Tool Co., addressed the members on "Hardening and Tempering of Tools", and G. E. Batten, manager of sales, Ludlum Steel Co., discussed "The Troubles of a Steel Salesman."

During the evening, the retiring secretary, D. Hanson Grubb, Pacific Scientific Co., was presented with an artistic floor lamp, as a token of esteem by his fellow members. Mr. Grubb has actively promoted the interests of the society since its inception. Presentation was appropriately made by S. R. Thurston.

Certificates were distributed to the 51 members successfully completing the course in Steel Treating which was given over a 17 weeks' period, and included lectures and laboratory work.

Members welcomed back the reelected Chairman, F. B. Drake, who had just returned from the Gear Manufacturers' Convention. Other officers installed at the meeting were: Dr. W. J. Crook, Vice-Chairman; C. R. Owens,

1926

Secretary; and for Executive Committee: S. C. Alexander, William Cohn, H. E. Gray, J. H. Gumz, Cecil Hawley, E. H. Kettner, A. C. Naish, Fred L. Wight, J. H. Wilson, and Roy T. Wise.

It was announced that there would be no July meeting because of the vacation period and also gives the new committee an opportunity to get started on the next year's work.

C. R. Owens.

LOS ANGELES CHAPTER

The last regular meeting of the Los Angeles Chapter of the American Society for Steel Treating was held in the club rooms of the Los Angeles Creamery, July 13, 1926.

Forty-five members were present and after a very enjoyable dinner, Chairman C. A. Stiles called the meeting to order. Various committee reports were read and it was unanimously voted that the chapter purchase a balopticon with screen which is to remain the property of the local chapter and be kept by the officers for use at chapter meetings.

W. P. Balderston of the Pacific Scientific Company of Los Angeles was then introduced and read a paper on Heat Treatment by the Rockwell Dilatometer which proved to be very interesting and gave the members present a very good idea regarding heat treatment by dilatation.

Following Mr. Balderston's paper, Prof. Howard W. Clapp of the Pasadena Institute of Technology addressed the society. This being the regular meeting night for the course in Practical Metallurgy and Heat Treatment of Steel, the Professor gave the third lecture which covered the puddling furnace, the Bessemer and open hearth. He spoke in detail on the chemistry of purification of pig iron, the second step in changing iron ore to any useful product other than cast iron. His slides shown on the screen were very interesting.

From the interest shown in Prof. Clapp's course, it is well worth the effort for each member and friend enrolled to attend each lecture.

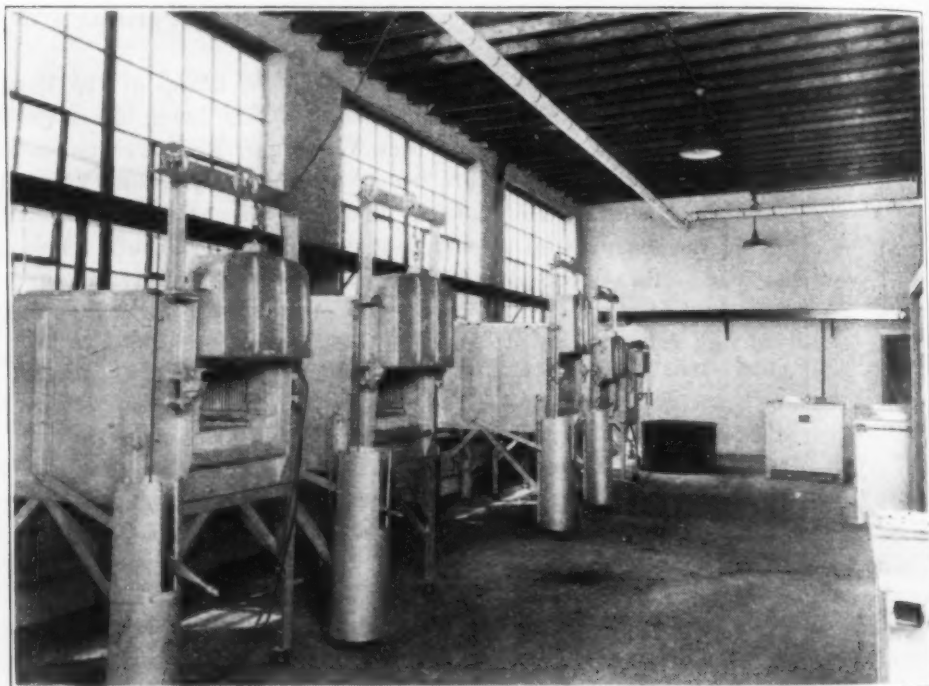
E. C. Black.

Items of Interest

A NEW industrial enterprise has been established to manufacture steel working tools from a new metal known as Pyrotung. The new company is known as the Pyrotung Manufacturing Company and a modern plant has been built in Chicago equipped with the latest appliances for producing tools made under entirely new manufacturing methods developed by this company.

Some years ago the interests associated with this company originated and perfected a method of manufacturing metal working tools that shows a distinct departure from those long in use, according to the report recently issued by this Company.

It is stated that possibly, the most important development undertaken by this new company has been the perfection of certain new processing formulas



used in the treatment of the tools that give their product a degree of toughness and hardness and a heat resisting factor without brittleness that is producing most remarkable results in actual practice under manufacturing conditions.

The Pyrotung products consist of various kinds of tools for machine tool use such as lathe bits, planer and shaper tools and special tools, also flat beaded drills, flat beaded track bits, bond hole drills, etc. Records which the company has been able to show, indicate a longer life of its tools between

September

grindings; in many cases 5 to 8 times under similar feed and speed conditions.

Pyrotung heavy duty planer tools used in frog and switch manufacturing work have handled 150 switch points without grinding, and that similarly long life results are being secured with its track drills while working under the maximum cutting feeds and speeds. It is said that Pyrotung tools have a greater manufacturing producing capacity than other tools for similar work and are likewise securing commercial results on metal classed hereto as unmachinable.

The Pyrotung plant is equipped with specially designed electric furnaces and pyrometer recording and controlling equipment.

A complete laboratory department is maintained and the Pyrotung Company, through its metallurgical engineering department and laboratory equipment, extend scientific service to the trade.

An important part of the Pyrotung Manufacturing Company organization is the commercial heat treating division, equipped for handling heat treating work in all of its branches. The newly developed Pyrotung formulas enables the commercial heat treating department to produce a more uniform toughness and hardness in its operations of heat treatment than has been possible to secure heretofore.

The Pyrotung Company is prepared to handle in its commercial heat treating division, such products as shop tools of all kinds, machine parts, gears, forming rolls, shear blades, punches and dies, milling cutters, hobs, coal-cutter teeth, oil tools, etc.

The new plant is located in the manufacturing section on the southwest side of Chicago, at 730 West 50th Street. The personnel of the company consists of men previously identified with steel, metallurgical engineering and commercial heat treating industries.

Considerably more iron ore, pig iron, and ferroalloys were produced and shipped in the United States in 1925 than in 1924, according to figures compiled in the Bureau of Mines, and recently made public by the Department of Commerce.

The iron ore mined in 1925 amounted to 61,907,997 gross tons, an increase of 14 per cent as compared with 1924. The shipments of iron ore in 1925 amounted to 63,924,763 gross tons, valued at \$161,796,886, an increase in quantity of 23 per cent and in value of 6 per cent as compared with 1924. The average value per ton of iron ore at the mines in 1925 was \$2.52, which is 39 cents less than in 1924. The stocks of iron ore at the mines at the end of 1925 amounted to 10,795,630 gross tons, compared with 12,410,619 tons at the end of 1924, a decrease of 13 per cent.

The shipments of pig iron from blast furnaces in 1925, amounting to 36,814,702 gross tons, valued at \$739,316,333, showed an increase of 19 per cent in quantity and 11 per cent in total value. The general average value of pig iron of all grades at the furnaces in 1925 was \$20.08, a decrease of \$1.33 from the value in 1924.

The production of pig iron in 1925, exclusive of ferroalloys, was 36,124,678 gross tons, compared with 30,869,199 tons in 1924. In the production of pig iron in 1925 there were used 62,029,734 gross tons of domestic iron ore and

manganiferous iron ore; 2,337,767 tons of foreign iron ore and manganiferous iron ore; and 5,137,068 tons of cinder, scale and scrap, a total of 69,504,569 tons. An average of 1.924 gross tons of metalliferous materials was consumed per ton of pig iron made in 1925, as compared with 1.896 tons in 1924.

An increase of 24 per cent in the shipments of ferroalloys from furnaces

**Iron ore mined in the United States, 1924-1925, in gross tons
(Exclusive of ore containing 5 per cent or more of manganese)**

State	1924	1925	Percentage of Increase or Decrease in 1925
Alabama	6,993,613	7,093,250	+ 1
California	435	352	- 19
Colorado	4,762	8,642	+ 84
Georgia	113,039	78,835	- 30
Michigan	12,350,755	14,490,529	+ 17
Minnesota	31,902,085	36,856,244	+ 16
Missouri	79,847	40,043	- 50
Montana	3,913	3,672	- 6
New Jersey	65,197	202,942	+211
New Mexico	189,371	172,959	- 9
New York	255,832	141,534	- 45
North Carolina	12,525	22,011	+ 76
Ohio	244	2,410	+888
Pennsylvania	807,208	955,955	+ 18
Tennessee	179,853	164,717	- 8
Utah	164,154	270,029	+ 64
Virginia	89,792	96,272	+ 7
Washington	1,700	830	- 51
Wisconsin	690,058	817,149	+ 18
Wyoming	363,096	489,622	+ 35
	54,267,419	61,907,997	+ 14

**Iron ore mined in the United States, by mining districts and varieties, 1924-25,
in gross tons**

(Exclusive of ore containing 5 per cent or more of manganese)

District	Hematite	Brown Ore	Magnetite	Carbonate	Total	Percentage of Increase or Decrease in 1925
1924						
Lake Superior ^a	44,796,766	.....	44,953	.....	44,841,719	.....
Birmingham	6,214,381	296,931	.....	.....	6,511,312	.....
Chattanooga	376,693	171,004	.....	.....	547,697	.....
Adirondack .....	.....	.....	197,437	.....	197,437	.....
Northern New Jersey and south-eastern New York	.....	.....	110,626	.....	110,626	.....
Other districts	^b 714,460	^b 346,224	994,695	3,249	2,058,628	.....
	^b 52,102,300	^b 814,159	1,347,711	3,249	54,267,419	.....
1925						
Lake Superior ^a	52,056,663	.....	.....	.....	52,056,663	+16
Birmingham	6,312,207	323,599	.....	.....	6,635,806	+ 2
Chattanooga	259,843	96,877	.....	.....	356,720	-35
Adirondack .....	.....	.....	328,745	{ }	328,745	+ 7
Northern New Jersey and south-eastern New York	.....	.....		
Other districts	^b 917,977	^b 464,124	1,143,259	4,703	2,530,063	+23
	^b 59,546,690	^b 884,600	1,472,004	4,703	61,907,997	+14

^aIncludes only those mines in Wisconsin which are in the true Lake Superior district.

^bSome hematite included with brown ore.

is shown for 1925. The shipments of ferromanganese in 1925 increased 9 per cent and those of spiegeleisen increased 26 per cent. The average values per ton reported for ferromanganese and spiegeleisen at the furnaces in 1925 were, respectively, \$102.39 and \$25.10.

Iron ore shipped from mines in the United States, 1924-25, by States
(Exclusive of ore containing 5 per cent or more of manganese and of ore sold for paint)

State	1924		1925		Percentage of Increase or Decrease	
	Gross Tons	Value	Gross Tons	Value	Quantity	Value
Alabama	6,557,596	\$13,927,551	6,891,081	\$14,134,677	+ 5	+ 1
California	435	(a)	352	(a)	- 19	....
Colorado	4,702	(a)	8,642	(a)	+ 84	....
Georgia	112,059	285,128	79,488	231,683	- 29	-19
Michigan	11,248,641	35,605,902	15,254,003	40,926,315	+ 36	+15
Minnesota	31,076,114	93,311,092	38,022,237	96,083,485	+ 22	+ 3
Missouri	79,847	405,622	40,043	(a)	- 50	....
Montana	3,913	10,846	3,672	10,244	- 6	- 6
New Jersey ...	101,123	420,488	164,523	678,021	+ 63	+61
New Mexico ..	189,371	(a)	172,959	(a)	- 9	....
New York	303,386	1,448,616	413,517	1,988,735	+ 36	+37
North Carolina.	12,525	32,512	22,011	49,511	+ 76	+52
Ohio	244	(a)	2,410	(a)	+888	....
Pennsylvania ..	807,411	1,881,122	917,255	2,149,800	+ 14	+14
Tennessee	179,293	431,682	164,073	369,144	- 8	-14
Utah	164,154	234,348	268,529	361,251	+ 64	+54
Virginia	91,759	250,279	76,302	174,454	- 17	-30
Washington	1,700	(a)	830	(a)	- 51	....
Wisconsin	786,006	2,044,762	933,214	2,260,388	+ 19	+11
Wyoming	363,096	(a)	489,622	(a)	+ 35	....
Undistributed ..	.....	b1,017,155	.....	b1,379,178	....	....
	52,083,375	151,307,105	63,924,763	160,796,886	+ 23	+ 6

a Included under "Undistributed."

b This figure includes value for States entered as "(a)" above.

Pig iron shipped from blast furnaces in the United States, 1924-25, by States.

State	1924		1925		Percentage of Increase or Decrease	
	Gross Tons	Value	Gross Tons	Value	Quantity	Value
Alabama	2,667,361	\$55,791,228	2,910,370	\$57,777,275	+ 9	+ 4
Colorado	(a)	(a)	(a)	(a)	....	....
Illinois	2,695,961	59,299,519	3,600,484	74,937,781	+34	+26
Indiana	2,571,411	52,507,720	3,350,747	64,807,575	+30	+23
Kentucky	99,055	(a)	153,935	(a)	+55	....
Maryland	539,188	(a)	693,523	(a)	+29	....
Massachusetts ..	50	(a)	.....	.....	....	....
Michigan	650,333	15,225,990	831,435	18,452,346	+28	+21
Minnesota	189,033	(a)	276,240	(a)	+46	....
Missouri	21,371	(a)	3,758	(a)	-52	....
New Jersey	(a)	(a)	(a)	(a)	....	....
New York	1,914,545	38,150,486	2,151,036	40,435,443	+12	+ 6
Ohio	7,434,487	159,701,131	8,857,615	173,418,068	+19	+ 9
Pennsylvania ..	10,962,288	237,052,035	12,537,809	258,140,674	+14	+ 9
Tennessee	126,660	2,782,154	95,186	2,014,176	-25	-28
Utah	(a)	(a)	126,746	(a)	....	....
Virginia	94,462	2,268,022	97,884	2,237,749	+ 4	- 1
West Virginia..	453,944	9,884,019	499,047	9,416,095	+10	- 5
Wisconsin	172,435	3,945,369	226,712	4,836,952	+31	+23
Undistributed ..	b471,545	b28,471,299	b402,175	b32,842,199	....	....
	31,064,129	665,078,972	36,814,702	739,316,333	+19	+11

a Included under "Undistributed." b Includes figures for States marked "(a)".

The production of ferromanganese in 1925 was 259,780 gross tons, averaging 78.93 per cent of manganese, and containing 205,046 tons of manganese (metal). In the production of ferromanganese in 1925 there were used 519,139 gross tons of foreign manganese ore, 34,942 tons of domestic manganese ore, 4,949 tons of iron ore, and 11,072 tons of cinder, scale, and scrap. The quantity of manganese ore used per ton of ferromanganese made in 1925 was 2.133 gross tons; in 1924 it was 2.186 tons; and in 1923 it was 2.243 tons. Of the foreign manganese ore consumed in 1925, 207,238 gross tons was from Brazil and averaged 43.52 per cent of manganese; Russia furnished 194,006 tons, averaging 48.17 per cent of manganese; India 68,326 tons, averaging 50.42 per cent; Africa 33,582 tons, averaging 46.97 per cent; and the remainder was from Chile, China, Cuba, and Porto Rico and averaged between

Ferroalloys shipped from furnaces in the United States, 1924-25.

Variety of Alloy	1924		1925	
	Gross Tons	Value	Gross Tons	Value
Ferromanganese ^a	232,821	\$23,533,668	254,005	\$26,006,439
Spiegeleisen	76,179	2,354,731	95,890	2,407,226
Ferrosilicon (7 per cent or more silicon)...	150,021	7,558,984	221,387	11,405,060
Ferromolybdenum	107	254,970	210	236,957
Ferrotungsten	741	1,110,553	1,238	1,991,123
Ferrovandium	1,355	3,641,724	1,841	4,843,635
Other varieties ^b	36,020	4,795,318	41,651	6,157,660
	497,244	43,249,948	616,222	53,048,100

^aIncludes a small quantity of silico-manganese.

^b1924: Ferrochromium, ferrophosphorus, ferrotitanium, ferrozirconium, and zirconium-ferrosilicon; 1925: Ferrochromium, ferrophosphorus, ferrotitanium, ferrouanium, ferrozirconium, and zirconium-ferrosilicon.

42.44 and 52.75 per cent of manganese. The average manganese content in the total foreign ore consumed in 1925 was 46.41 per cent. The improvement in metallurgy in the manufacture of ferromanganese is evidenced in 1925 by the recovery of 80.36 per cent of the metallic manganese contained in all ore consumed, whereas during 1918 a loss of from 10 to 40 per cent of the manganese contained in the ore was entailed in the manufacture of ferromanganese.

Two new bulletins of the series of technical articles on nickel steel are now being distributed by The International Nickel Company, 67 Wall Street, New York. Bulletin No. 6 entitled "Alloy Steel Reduces Die Block Costs" tabulates the comparative costs of producing commercial forgings with carbon steel and nickel steel die blocks, and the savings effected by the use of the latter material. Bulletin No. 7—"Automobile Design and Automotive Steels" sets forth the factors influencing the design of the modern motor car and the selection of suitable steels to be used in its construction with typical calculations illustrating the methods used to determine the stresses and factors of safety in various automotive parts.

Copies of previous bulletins of this series, as well as loose-leaf binders to facilitate filing them and increase their reference value, are available and will be furnished on request.

The Carborundum Company of Niagara Falls, N. Y., announces that George

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890	2,407,226
387	11,405,060
210	236,957
238	1,991,123
841	4,843,635
651	6,157,660
222	53,048,100

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R. Rayner, vice-president in charge of sales, will continue as head of that department. Announcement is also made of the appointment of William MacGregor and S. F. Courter as Mr. Rayner's assistants. Both Mr. MacGregor and Mr. Courter will carry the titles of general sales managers, each being in charge of a sales division, and will succeed in this work the late W. W. Sander-son.

Mr. MacGregor was formerly sales manager of the Coated Abrasive Division of The Carborundum Company having in charge the sales promotion of Carborundum paper and cloth, Carborundum Brand garnet paper and cloth, Carborundum Brand waterproof finishing papers and Aloxite paper and cloth.

Mr. Courter was formerly a district sales manager and was in charge of the office, warehouse and sales force in Philadelphia. He has been succeeded in that office by W. J. Griffith.

The Mindoro, owned by H. H. Harris, president of the General Alloys Company, of Boston, (Manufacturers of Q-Alloys), is being brought to



Chicago by her owner especially to attend the Steel Show, and do her part in the Entertainment program.

Mindoro is a 90-foot auxiliary yawl, having four staterooms, and accommodating ten guests in addition to her crew of six men, and is a thoroughly

sea-going craft, having cruised extensively in the Mediteranean, West Indies, etc. She is a recent winner of the Boston to Bar Harbor Race, and has many victories to her credit.

Harry Harris figured that after seven years of plugging alloys that "Stand-up-under-Fire" he was entitled to a vacation and consequently bought the Mindoro when his power yacht "Southwind III" burned off the coast of Maine last August, fitted her out for a West Indies cruise and sent her to Florida with her crew to await his coming. Rapidly increasing business necessitating additions to the G. A. Co's Boston plant kept his nose to the grindstone however, and Harry never went near her in Florida. In fact, his first sight of the boat this year was when she came through the Erie Canal to Buffalo, enroute to Chicago, via Detroit. At Detroit she had a new power plant installed, giving her a speed of 11 miles per hour, making her the fastest auxiliary sail yacht of her size afloat, under power. She will make the run of 600 miles from Detroit, through Lakes St. Claire, Huron, and Michigan in four days with stopover at Mackinac, reaching Chicago about September 18.

The Mindoro will be anchored off Municipal Pier after her 2500 mile trip.

The General Refractories Company, of Philadelphia, manufacturers of fire clay, silica, magnesia, chrome, and high alumina refractories, announces through its new folder a distinctively different refractories cement.

Because of the fact that this cement is of a neutral character it is exceedingly practical in the metallurgical industry on account of its resistance to acid, as well as basic slags. As a mortar and protective coat for boiler setting and similar furnaces where coal and ash slags are formed, it is especially desirable, and in ceramic kilns it has demonstrated without question its ability to protect the brickwork from the erosion of the gasses, as well as the slagging or surface fusion of fire brickwork in the fire boxes or bag-walls, which is always present in unprotected fire brickwork.

This company will gladly have their representative call on any interested parties, and will send a sample of this material upon request to their office, 117 South 16th Street, Philadelphia.

Holcroft and Company of Detroit, Michigan, announces the opening of their branch offices at Cleveland and Chicago. H. M. Smith is district sales manager of the Cleveland branch with offices at 405 Sloan Building; and C. H. Martin is district sales manager with offices in Room 802 Putnam Building, 10 North Clark Street, of the Chicago branch.

F. H. Chapin has recently been elected president of the National Acme Company of Cleveland. He succeeds A. W. Henn, who is now chairman of the board. The record of his achievement is from a farmer boy in Iowa to the presidency of a \$12,000,000 company before the age of 50.

Kearney and Trecker Corporation, Milwaukee, has moved its offices at Indianapolis to larger quarters in the Continental Bank Building. The office is in charge of R. W. Ott.

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